AGRICULTURAL ENGINEERING

FEBRUARY • 1952

Loads Imposed on Power-Take-Off Shafts by Farm Implements *Merlin Hansen*

A Method of Approximating Depth and Spacing of Drain Laterals *Phelps Walker*

Heat Transfers in Using Wind Machines for Frost Protection *F. A. Brooks, C. F. Kelly, et al*

The Effectiveness of Heaters Used for Frost Protection *Robert A. Kepner*

Automatic Electric Controls for a Poultry Laying Battery *Stanley J. Otis*

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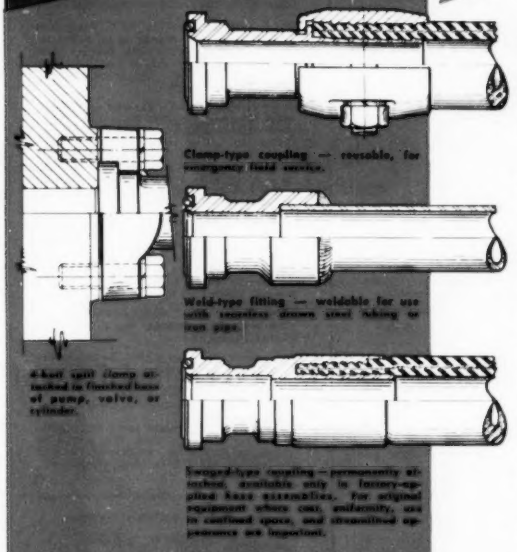
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CONTENTS FOR FEBRUARY, 1952

Vol. 33, No. 2

EDITORIAL 65

LOADS IMPOSED ON POWER TAKE-OFF SHAFTS BY FARM IMPLEMENTS 67
By Merlin Hansen

A STUDY OF POWER TAKE-OFF DRIVES 70
By T. H. Morrell

DEPTH AND SPACING FOR DRAIN LATERALS AS COMPUTED FROM CORE SAMPLE PERMEABILITY MEASUREMENTS 71
By Philip Wilcox

HEAT TRANSFERS IN CITRUS ORCHARDS USING WIND MACHINES FOR FROST PROTECTION 74
By F. A. Brooks, C. F. Kelly, D. G. Rhoades, and H. B. Sehultz

EFFECTIVENESS OF HEATERS FOR FROST PROTECTION IN CITRUS ORCHARDS 79
By Robert A. Kepner

A DEW POINT MOISTURE INDICATOR 85
By Norton C. Ives

AUTOMATIC CONTROLS FOR POULTRY LAYING BATTERY 88
By Stanley J. Otis

NEWS SECTION 91

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Aetna Ball & Roller Bearing Co.	57	Johns-Manville Corp.	103
Allis-Chalmers Mfg. Co.	101	Link Belt Co.	54, 61
Anchor Coupling Co., Inc.	89	Marlow Pumps	106
Armco Steel Corp.	107	Massey-Harris Co.	105
Austin-Western Co.	52	Mechanics Universal Joint Div. Borg-Warner Corp.	97
Blood Brothers Machine Co.	61	Morse Chain Co.	62, 63
J. I. Case Co.	2nd cover	New Departure, Div. of General Motors	3rd cover
Chain Belt Co.	54, 55	Oberdorfer Foundries, Inc.	94
Clark Equipment Co.	59	Portland Cement Assn.	96
Diamond Chain Co.	56	Rain Bird Sprinkler Mfg. Co.	108
Douglas Fir Plywood Assn.	104	Rochester Mfg. Co.	100
Electric Wheel Co.	112	Spraying Systems Co.	108
Fafnir Bearing Co.	58	Stow Mfg. Co.	92
French & Hecht Div. Kelsey-Hayes Wheel Co.	110	The Texas Co.	99
Harry Ferguson, Inc.	102	The Timken Roller Bearing Co.	4th cover
Hyatt Bearings Div. General Motors Corp.	60	The Torrington Co.	53
Ingersoll Steel Div. Borg-Warner Corp.	66	U. S. Steel Co.	95
International Harvester Co.	93	U. S. Treasury	111
International Nickel Co.	109	Wisconsin Motor Corp.	98

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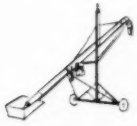

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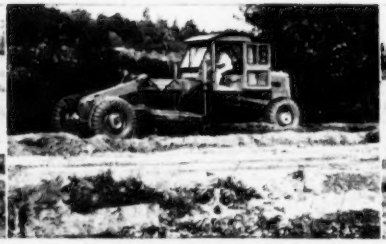

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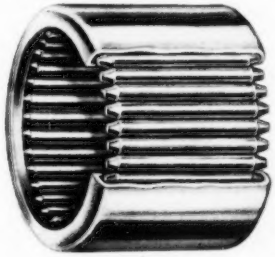

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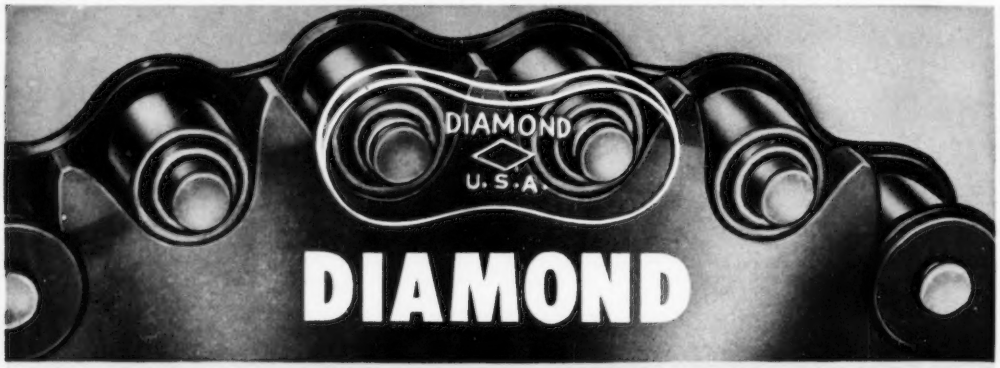

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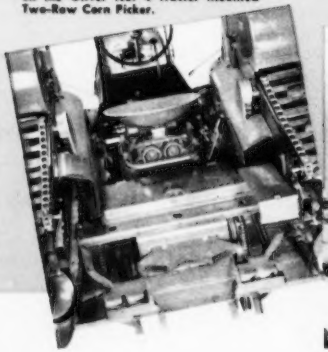

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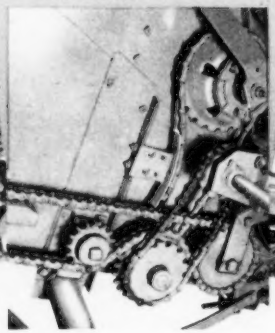

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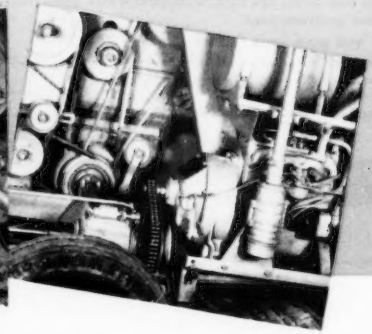

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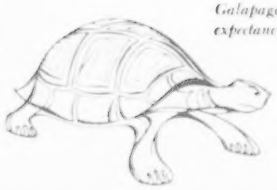

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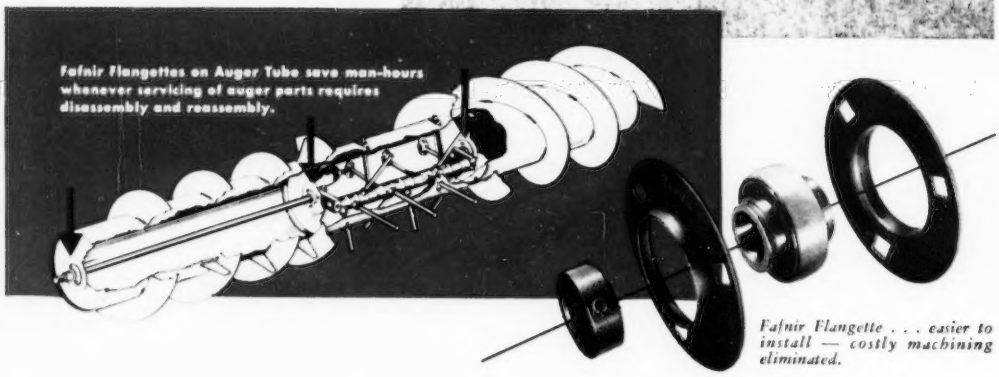
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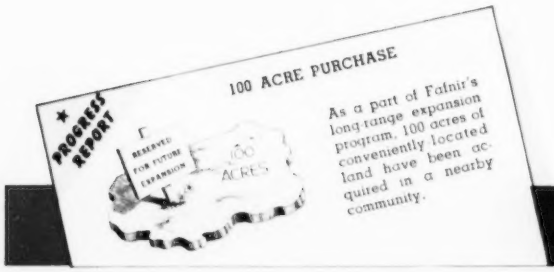
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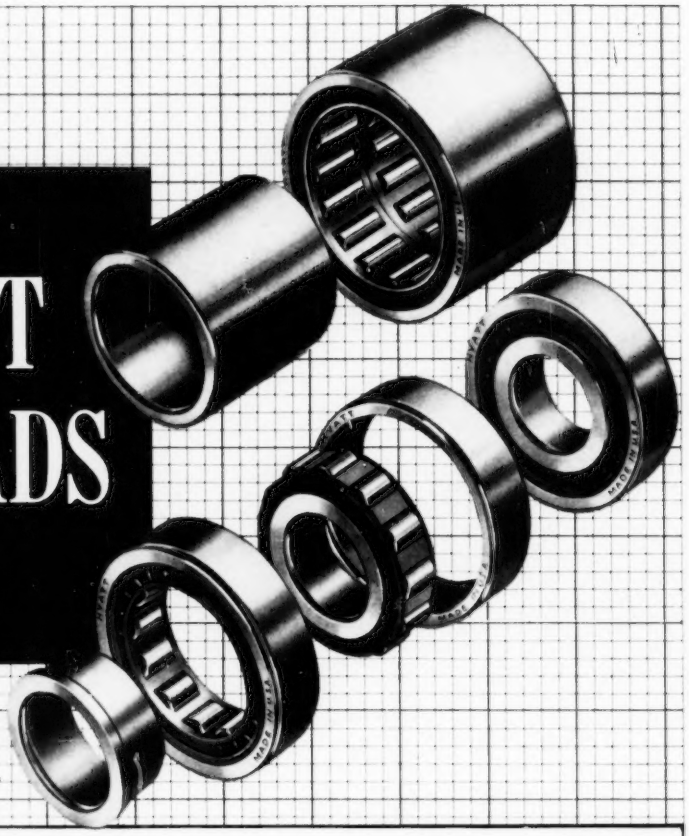

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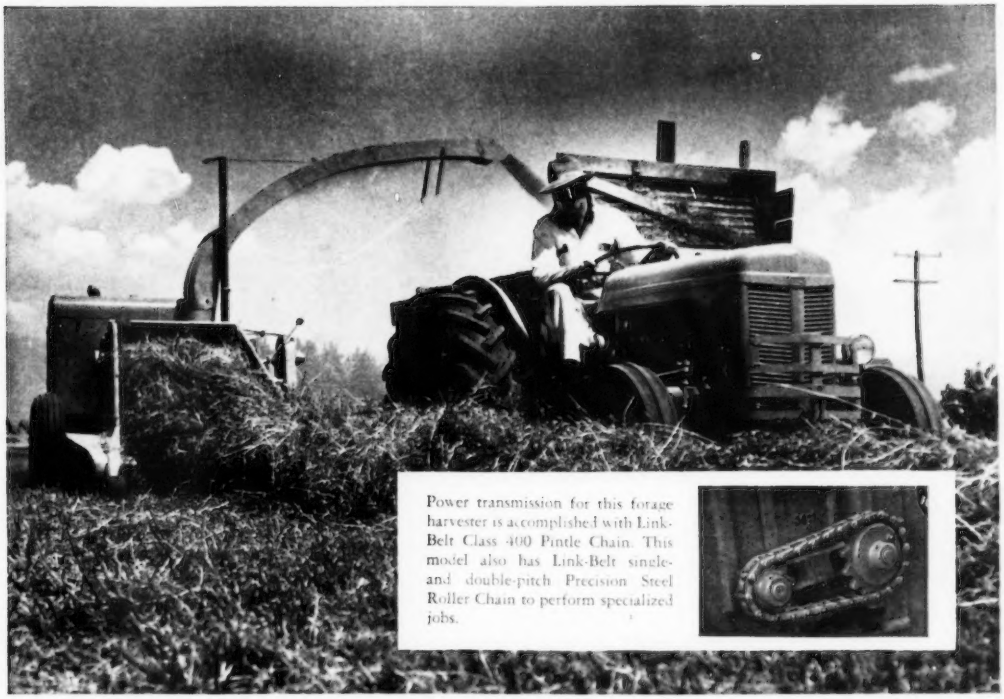

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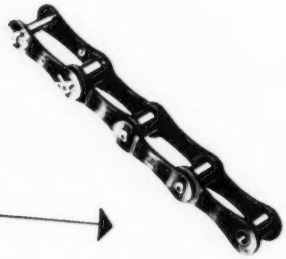
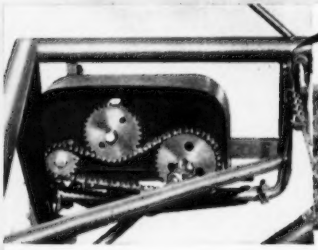
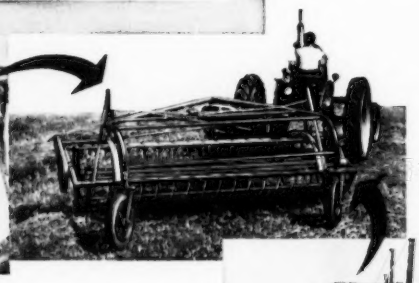
2. Morse Rockford Clutch in main front-wheel drive delivers dependable, trouble-free operation despite exposure to dust and corrosive sprays.

3. Morse Double-Pitch Roller Chain transmits power from counter-shaft to front wheel. It costs less, weighs less and gives long, trouble-free service life comparable to that of Morse Standard Roller Chain.

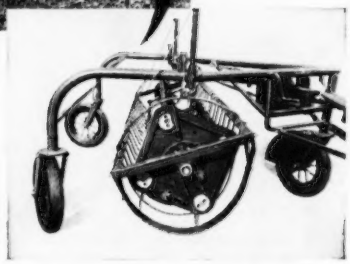






New Holland Side Delivery Rake

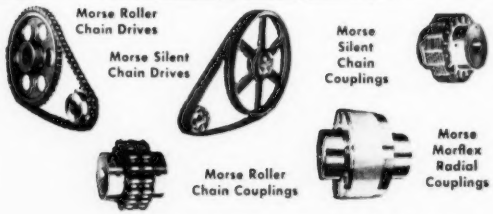
1. Morse Standard Roller Chain and Morse Stock Sprockets in rake's transmission unit. Morse Roller Chain Drives transmit power with less than 1% friction loss. They are positive, won't slip. They operate equally well on long or short centers, give extra-long, trouble-free service life.



2. Two sets of Morse Standard Roller Chains drive pitch control mechanism.

Ask the Morse Man for power transmission information!

From coast to coast there are Morse branch offices and representatives to give you quick information and service when you want it—where you want it. Ask the Morse Man first in any case!


Morse Roller Chain Drives
Morse Silent Chain Drives
Morse Silent Chain Couplings
Morse Roller Chain Couplings
Morse Morflex Radial Couplings

transmission products help you design better farm machinery

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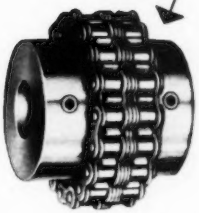
Examine the applications of Morse products shown at left. Then get detailed information on the ones that fit your needs. Talk to your nearest Morse Man, or write direct to Morse.



Morse DRC Flexible Coupling is used on shaft of pump that activates hydraulic lift. The Morse DRC Coupling automatically compensates for any slight parallel or angular misalignment. Though compact, it provides large horsepower capacity. It may be easily disassembled by unwrapping chain.

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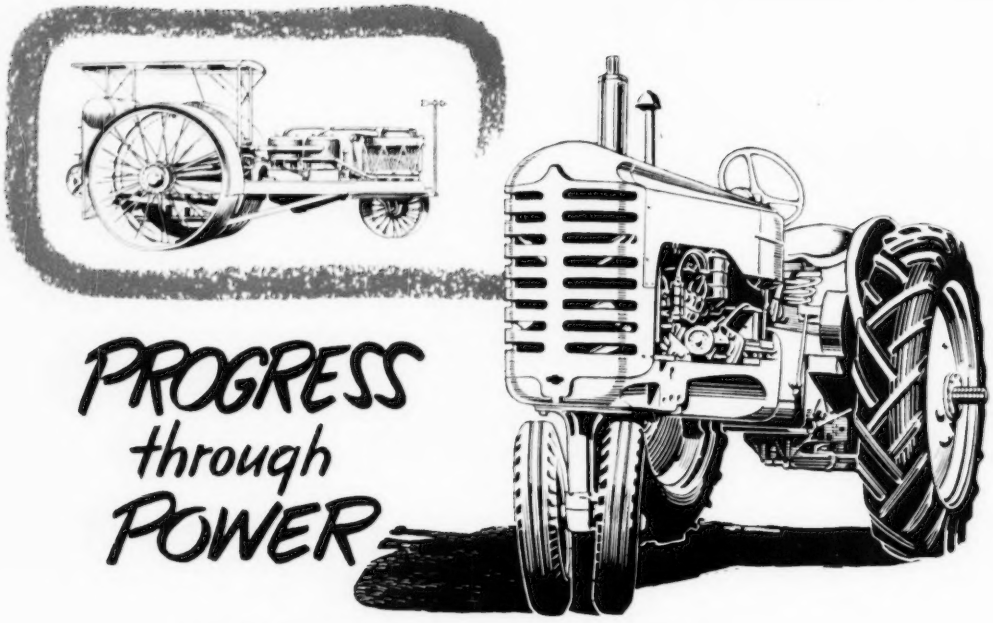

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Half the size and twice the power — that's today's tractor! And the tractor's vast improvements are but part of the story.

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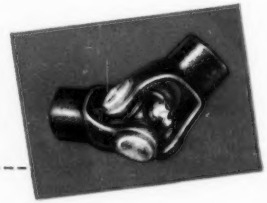

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EDITORIAL

Dynamic Agriculture

COMPARATIVELY speaking, agriculture in the United States is moving along at a jet-propelled pace. By the time the "whoosh" of statistics on last year's performance reaches us, agriculture is somewhere else. About the only ones who can really keep up with it are those who are riding along as members of the crew.

The rest of us who may have occasion periodically to bring ourselves up to date on agricultural information, equipment, methods, processes, and thinking, must learn to expect to find them somewhere ahead of where we may have seen them yesterday, last week, or last year.

This is important particularly in planning for agriculture's part in national defense, general public policy on agriculture, and business operations to serve agriculture or utilize some of its products.

It is difficult because we tend to think of agriculture as many of us knew it personally 10, 20, or 40 years ago.

We thought farms were fairly well mechanized ten years ago, but since then the number of tractors and other machines on farms has doubled. During the same period their number of work animals has been reduced to less than half of those in use in 1941.

At the same time farm population has decreased 4½ million, or one person on almost every farm, while our total population has increased additional millions and our commitments to help feed other populations have increased.

Output per man-hour has increased enough to considerably increase our total farm production per year, even with a reduction in the number of man-hours used on farms.

The problem of the surplus farm, the surplus farmer and the surplus of farm products in the United States has, in general, disappeared, and does not seem due to return in the near future. Shortages are more likely to occur.

These surpluses were valuable emergency reserves for defense in 1941 and 1942. Agricultural production capacity for the current defense emergency has to be figured differently than in 1941. Normal and emergency food and fiber production now calls for the same metals, the same fuels, and much of the same manpower and chemicals as military and industrial mobilization for defense.

A major opportunity has developed for industries which can find the materials, engineers and other man power to provide farmers with additional means for further increasing their output per man-hour.

Increased productivity per farm man-hour, together with the growing assured market, spell opportunity for the processors of farm products.

Farming will continue to present problems to farmers, administrators of public agencies and all who either buy from or sell to farmers. Those problems will be minimized, however, if we can remember that agriculture is on the move.

Mechanisms for Conservation

SOME recent strong suggestions that the United States adopt a national land-use policy have drawn fire from advocates of states rights and strong private enterprise.

Without taking sides in the controversy or attempting to tell anyone what he should think, we would invite consideration to one special aspect of the problem.

Soil and water conservation, use of land and water in agriculture and some other phases of land-use policy or practice involve agricultural engineering. A land-use policy involves a question of the mechanics of human organization and administration which may enable engineers to work most effectively. It involves a question of ways and means available to the majority of the people for utilizing engineering to protect their interests in important natural resources.

For the purposes of this discussion the federal government may be considered objectively as one of many instruments devised and maintained by the people to promote and protect their common interests more effectively than they could as individuals. All of these instruments have limitations and weaknesses as well as strong points.

There is a legitimate question as to the phases of land use and conservation in which the interests of the public may be protected most advantageously by federal, or state, or private mechanisms.

The mechanisms of private enterprise, local government, and federal government have all been used to produce some remarkable examples of sound and farsighted conservation. Those same mechanisms likewise have all been associated with some glaringly wasteful, senseless, and selfish destruction of natural resources. It appears that the difference in results has been due more to the differences in viewpoint and interests of individuals than to the mechanisms through which they achieved conservation or exploitation.

A united land-use policy in the thinking of a majority of our people could apparently give a tremendous boost to conservation. A federal land-use law passed through the apathy rather than the active support and effective representation of a majority of voters would be something different.

Would a national land-use policy actually give conservationists an improved instrument and increase the effectiveness of their work? Would it supplant conservation policies, procedures, and organizations already proving effective in limited areas? Much would depend on how the law would be written, how intelligently it would be administered, and how well it would be supported by an informed public opinion.

In the absence of any one clearly superior mechanism for enforcing or otherwise achieving conservation and sound land use, it would appear to be good engineering to keep the way open for full use to that end of all available mechanisms through which the human forces favoring conservation may be applied.

Mulch and Fertilizer

CORN has long been maligned as a soil robber and an invitation to erosion. Recently, however, Dr. George Scarseth is reported to have shown that the trouble may be with orthodox ideas of how corn should be produced, rather than with the crop.

Dr. Scarseth is an ASAE member who isn't afraid to entertain and test some unorthodox ideas. An agronomist with some of the outlook of an industrial engineer, he experimented with a part of his corn production line. He left out some operations which looked as if they might be expensive luxuries having little influence on quantity and quality of production.

Without plowing or other soil preparation he cut through a heavy mulch of stalks and weeds from the previous year's 30-bu operation, to put seed and crop feed in the ground.

He didn't worry about weeds to the extent of cultivating in the usual sense. Two shallow diskings, plus a split band of starting fertilizer, gave the corn a head start and it kept ahead of the weeds.

Perhaps the most significant result of his experiments was that fertilizing up to 1100 lb of 10-10-10 barely raised his yield above the break-even point, but that same treatment plus 200 lb of ammonium nitrate side-dressing boosted his net return per acre by $99.

Some agricultural engineering research on mulch tillage has shown rather indifferent results. Adequate fertilizer, properly timed and placed, may be the related factor which can give a sound cash profit foundation to mulch tillage as a soil and water conservation measure.

Dr. Scarseth says he simply tried out in one field several things the experiment stations have discovered. It added up to significant over-all efficiency, to the output above the break-even point which makes a production operation worth while.

If the corn belt is just beginning to learn how to grow corn, are there any farm practices or agricultural research results which may not merit further examination with an open mind?

"looking over a 4-leaf clover"

(with apologies to the song writer)

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†*Pat. Pend.*

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AGRICULTURAL ENGINEERING

VOL. 33 FEBRUARY, 1952 NO. 2

Loads Imposed on Power-Take-Off Shafts by Farm Implements

By Merlin Hansen
MEMBER ASAE

THE power take-off of agricultural-type tractors has steadily gained in use, as a means of transmitting power to implements, since it was introduced approximately thirty years ago. The continued expansion of this method for driving implements requires a satisfactory solution of a number of problems, one of which is the matter of providing a drive that is free from mechanical failures caused by torsional overloads.

The present-day farmer-user expects to operate practically any make or model of implement with any make of tractor. Therefore, the solution to these PTO-drive problems must be solved jointly by the tractor and implement industry. This fact has long been recognized. About seven years ago the industry, through the American Society of Agricultural Engineers and the Society of Automotive Engineers, approved a standard establishing the dimensional relationships necessary to permit any tractor to be hitched successfully to any implement. This standard, however, includes no load limitations. Therefore, each tractor manufacturer, each universal-joint manufacturer, and each implement manufacturer is obligated to use his individual experience in the matter of loads that are transmitted by the PTO drive. The result, of course, is that farmer-users sometimes encounter implement and tractor combinations that are not strictly compatible from the standpoint of torsional loads transmitted.

To the casual observer this problem of PTO torsional loads may at first appear elementary since it would seem that maximum PTO loads can be based successfully on the maximum horsepower available in the tractor engine. For example, a 35-hp engine will transmit an average working torque of 1100 lb-in at the standard PTO speed of 530 rpm.

Unfortunately, PTO drives designed on this basis are too often found inadequate. A study of tractor and implement PTO-drive failures experienced by the industry indicates these failures may be classified into five general types, namely,

1. Failures resulting from operation with the implement improperly hitched to the tractor
2. Failures resulting from insufficient telescoping of the PTO drive, or due to the universal joints reaching a locking angle while making a sharp turn
3. Failures due to too great a side load being applied to the tractor PTO shaft by V-belt or chain drives fastened directly to the tractor PTO
4. Fatigue failures due to moderately high torsional loads encountered at relatively high frequencies
5. Failures due to a single shock load of a magnitude exceeding the static strength of the drive.

The subject matter of this paper refers primarily to failures classified as types 4 and 5, but the over-all problem is not covered properly without recognizing the existence of types 1, 2 and 3.

A careful study of this general problem reveals that the torsional loads imposed on PTO drives are dependent upon the following factors:

1. The amount of kinetic energy stored in the rotating parts of the tractor
2. The moment of inertia of the rotating parts in the implement
3. The amount of resilience in the drive between the heavy rotating parts of the tractor and the rotating parts of the driven implement
4. The horsepower available at the PTO drive from the tractor
5. The horsepower required to operate the implement.

Contrary to popular belief, items 1, 2 and 3 are far greater factors in influencing the magnitude of peak PTO torsional loads than are items 4 and 5.

The magnitude of torque that is applied as a result of kinetic energy is dependent entirely upon how rapidly the applied load changes the rotating speed of the driving parts.

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1951, as a contribution of the Power and Machinery Division.

The author, MERLIN HANSEN, assistant chief engineer in charge of development, John Deere Waterloo Tractor Works of Deere Mfg. Co., Waterloo, Iowa.

AUTHOR'S ACKNOWLEDGMENTS: The author acknowledges the assistance of the following individuals and organizations for their valuable contributions in connection with the preparation of this paper: (a) W. F. Gustin, C. E. Williamson, D. C. Smiley, R. W. Goertz, J. F. Nesbit, W. M. Van Sus, M. J. Frey, and Miss Lois Moritz of the John Deere Waterloo Tractor Works' engineering divisions for conducting the tests necessary to secure the experimental data and for preparing the accompanying tables and charts; (b) Herman Linde of Deere and Co. for editorial advice; (c) the engineering divisions of the John Deere Ottumwa Works, the John Deere Des Moines Works, the John Deere Harvester Works, and the John Deere Spreader Works for making implements available and for establishing representative operating conditions during the tests; and (d) the manufacturers participating in the EEI engineering subcommittee on PTO drives for graciously consenting to include experimental data on their implements and tractors and for their viewpoints on PTO problems, including the following companies cooperating in this activity: International Harvester Co., Allis-Chalmers Mfg. Co., The Oliver Corp., Massey Harris Co., Minneapolis-Moline Co., Cockshutt Plow Co., Ltd., Fox River Tractor Co., J. I. Case Co., New Idea Division of Avco Mfg. Co., Dearborn Motors Corp., Mechanics Universal Joint Division of Borg-Warner Corp., Blood Brothers Machine Co., and Deere and Co.

TABLE 1. KINETIC ENERGY OF ROTATING PARTS AND TORSIONAL PROPERTIES OF PTO DRIVES OF CURRENT TRACTOR MODELS

TRACTOR MAKE AND MODEL	APPROX MAX HP OF TRACTOR	Σ OF ROTATING PARTS, LB-FT SEC²	E OF ROTATING PARTS AT RATED SPEED, FT-LB	TORSIONAL DEFLECTION OF PTO TRAIN AT T.P., DEGREES	TORSIONAL YIELD STRENGTH OF PTO TRAIN, LB-IN.	ENERGY PTO DRIVE WILL ABSORB AT T.P., FT-LB	RATIO E IN ROTATING PARTS TO PTO DRIVE
1	35	2.33	12,120	20	17,600	256	47.3 TO 1
2	25	1.32	11,300				
3	35	3.23	16,820	37	28,000	753	22.2 TO 1
4	45	6.17	33,700				
5	35	1.034	11,900	20	28,000	407	29.2 TO 1
6	25			14.5	20,200	213	
7	30			12.5	17,670	161	
8	30			17.5	25,000	318	

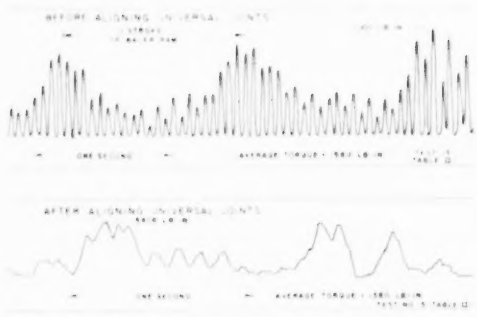

Fig. 1. Torquemeter charts showing the effect of improving the alignment of the universal joints in the PTO drive.

It is obvious, therefore, that if the PTO drive has sufficient strength to transmit the engine power plus sufficient strength and resilience to absorb the kinetic energy stored in the engine's rotating parts, mechanical failures of tractor drive parts due to torsional overloads will not be encountered. A number of current tractor models were analyzed in the following manner:

(a) Measuring the moment of inertia of the flywheel, clutch and crankshaft assembly as a unit. It is assumed that the greater portion of the kinetic energy available to the PTO drive is stored in this group of parts.

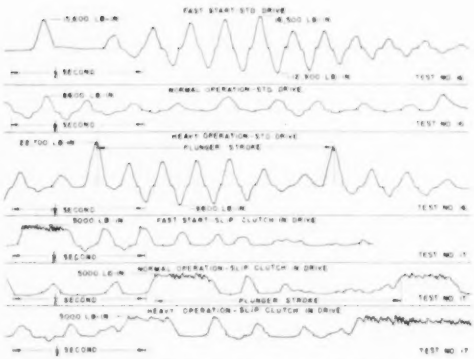

Fig. 2. Torquemeter charts (plotted from data in Table 2) showing the effect of a frictional slip coupling designed to operate at moderate torsional loads.

(b) Conducting a torsional load-deflection test on the PTO drive under static conditions to determine the amount of torsional "windup," and the load, at the yield point of the drive.

A summary of these tests is given in Table 1. In explanation of Table 1, it will be noted that tractor 1 has 12,120 ft-lb of kinetic energy stored in its rotating parts at rated engine speed. This is sufficient energy to raise 1212 lb a distance of 10 ft. A uniform torque of 4100 lb-in (35 hp) will absorb

TABLE 2. POWER TAKE-OFF TORSIONAL LOADS

TEST NO.	TRACTOR MODEL	APPROX. MAX. TRACTOR BHP	IMPLEMENT MAKE AND MODEL	COUPLING IN PTO DRIVE	MAX. STARTING TORQUE		MAX. OPERATIONAL TORQUE PEAKS		AVE. TORQUE UNDER NORMAL OPERATING CONDITIONS, LB-IN	WORK BEING PERFORMED
					WITH NORMAL CLUTCH ENGAGEMENT, LB-IN	WITH RAPID CLUTCH ENGAGEMENT, LB-IN	AVERAGE CONDITIONS, LB-IN	NEAR PLUGGED CONDITIONS, LB-IN		
1	1	55	ENSILAGE HARVESTER A	STANDARD	4900-6,400	10,800-15,370	4,680-6,390	5,450-7,140	2,720	CHOPPING HEAVY DRILLED CORN
2		55	ENSILAGE HARVESTER A	SPEC. SLIP		8,660*	5,112-5,723	6,025-6,865	3,200	CHOPPING HEAVY DRILLED CORN
3	2	40	ENSILAGE HARVESTER A	STANDARD		11,600	4,700-4,925	6,200-6,025	3,261	CHOPPING HEAVY DRILLED CORN
4	1	55	ENSILAGE HARVESTER B	STANDARD	2,600-4,000*		3,520-3,820	3,960-7,630*	2,390	CHOPPING HEAVY DRILLED CORN
5	1	55	FORAGE HARVESTER C	STANDARD		14,600	3,730-7,200	6,370-7,200	2,870	CHOPPING GREEN ALFALFA
6	1	55	FORAGE HARVESTER C	SPEC. SLIP		9,800-7,530*	5,230-6,700	6,100-8,700	3,270	CHOPPING GREEN ALFALFA
7	1	55	FORAGE HARVESTER C	STANDARD		12,500-10,900	6,060-7,460	9,500	3,600	CHOPPING GREEN ALFALFA
8		55	FORAGE HARVESTER C	STANDARD		21,400				ATTEMPTING TO START A PLUGGED MACHINE
9		55	CORN PICKER D	STANDARD	1,570-1,740	3,990	822-1,031		727	PICKING CORN
10		55	BALER E	STANDARD		18,300-20,600	5,860-7,470	12,100	1,140	BALING ALFALFA
11		55	BALER E	STANDARD	13,100		6,550-8,140	11,600-15,000	1,545	RECHECK OF TEST 10
12	1	55	BALER E	SPEC. SLIP	10,700-12,100*	10,700-12,100*	7,250-8,920	11,500-13,300*	2,250	BALING ALFALFA
13	1	55	BALER E	SPEC. SLIP	10,100*		8,600-11,100	10,350-12,600	1,580	BALING STRAW
14	2	40	BALER E	STANDARD	12,250		7,749-10,945	10,960-12,095	1,938	BALING ALFALFA
15	1	55	BALER E	STANDARD AND UNIVERSAL JOINTS ALIGNED			4,601-5,867		1,383	BALING ALFALFA
16	1	55	BALER F	STANDARD	16,500		8,600	22,700		BALING ALFALFA
17	1	55	BALER F	SPEC. SLIP	5,000*	5,000*	5,000*	5,000*		BALING ALFALFA
18	1	55	COMBINE G	STANDARD		10,100-16,600*	3,760	9,380	1,890	COMBINING WINDROWS
19	1	55	COMBINE G	SPEC. SLIP			7,150	7,760-9,130	1,700	COMBINING WINDROWS
20	1	55	COMBINE G	SPEC. SLIP		7,350-8,650*	4,160-4,200	7,470	1,600	STRAIGHT COMBINING
21	2	25	HAMMER MILL H	STANDARD	9,030	17,500-20,150	4,145	7,270	2,700	GRINDING EAR CORN
22	1	55	HAMMER MILL H	STANDARD	6,130		3,740	14,900	2,140	GRINDING EAR CORN
23	1	55	HAMMER MILL H	SPEC. SLIP	8,230*	8,230*		6,920	4,210	GRINDING EAR CORN
24	4	45	HAMMER MILL J	STANDARD	18,150	25,800	7,800	13,000	5,450	GRINDING EAR CORN

* SAFETY CLUTCH IN PTO LINE SLIPPED LIMITING TORSIONAL LOAD TO THIS VALUE

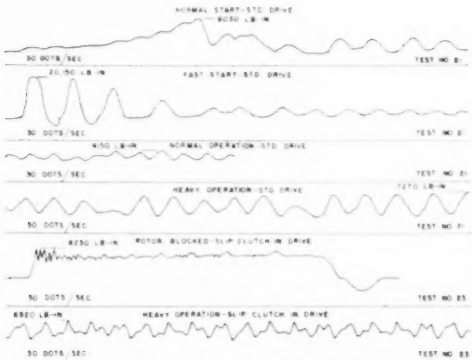

Fig. 3. Torquemeter charts (plotted from data in Table 2) showing the effect of a frictional slip coupling designed to operate at relatively high torsional loads.

this entire amount of energy in approximately 1.3 sec, but to absorb this amount of energy in 0.15 sec will require 34,400 lb-in of PTO torque. The foregoing example shows that preventing energy stored in rotating parts of the tractor from damaging PTO-drive parts can most efficiently be accomplished by incorporating adequate flexibility in the drive. The drive in tractor 1 referred to in Table 1 will "wind up" approximately 20 deg without damage to parts, but this 20 deg of windup will absorb only 2.1 per cent of the total energy available. At least 830 deg of torsional windup will be required to absorb all of the energy available in this tractor without exceeding 10,000 lb-in of PTO torque. At present, a slip coupling of some type is the only practical known method of absorbing this amount of energy.

The foregoing discussion gives a general insight into the loads that will be applied to the PTO drive if it is attached to any implement that is capable of rapidly changing the PTO speed. The implements in present-day use which are capable of imposing very rapid changes in PTO rotating speeds include balers, hammer mills, ensilage or forage choppers, combines, etc. Implements which are furnished with an independent engine, but offer a PTO drive as an alternate, are also generally in this class.

Tests were also conducted on a considerable number of PTO-driven implements suspected of imposing high torsional loads on the PTO drive to determine their operating characteristics. With some implements, changes were made experimentally in an effort to reduce the peak torsional loads to lower values. These revisions include

(a) Use of a frictional-slip coupling in the PTO line.

(b) Revising the angles of misalignment of the PTO universal joints.

The results of these tests are shown on Table 2. These tests were conducted with the implement and tractor combination performing operations that might be encountered in regular service. The results were secured with a torque meter in the PTO line. Both hydraulic and electronic measuring equipment were used depending entirely upon which instrumentation was available at the time or which was best adapted to the test in question. (A detailed description of the torque-measuring equipment is given in a paper entitled "Torque Measuring Apparatus and Technique" by W. E. Gustin, presented at the 1951 SAE National Tractor Meeting.) Figs. 1, 2, and 3 are representative torque meter charts.

A study of the foregoing data revealed the desirability of conducting a series of tests to measure the effect of universal-joint angularity on PTO peak loads. These tests were conducted with the tractor driving an electric dynamometer through the PTO and with the PTO drive operating through various angles of misalignment. The results of these tests are shown in Fig. 4. Also, representative torque meter charts are shown in Fig. 5.

After a study of the torsional loads which the tractor is capable of imposing on a PTO drive, and a review of loads which various implements can apply, it is only logical to make an investigation as to what loads the average PTO shaft can be expected to withstand. A series of fatigue tests were then conducted under fluctuating-load conditions to establish the fatigue characteristics of a representative design of PTO shaft. These tests were conducted with a tractor driving a dynamometer. The magnitude of the torque peaks was controlled by changing the misalignment of the universal joints in the PTO drive. The results of these tests are illustrated in Fig. 6. Fig. 7 shows representative torque meter charts of the test loads applied during this part of the investigation.

From Fig. 6 it is easily seen that high-frequency torsional peaks must be maintained below 6500 lb-in on this particular design of PTO shaft, but occasional torsional loads of much greater magnitude can be transmitted successfully if they do not occur too frequently.

CONCLUSIONS

1. *Average* horsepower or *average* torque measurements are of little value in establishing a sound basis for the design of PTO drive parts. Instead, maximum instantaneous torque values must be given principal consideration.

2. The peak torsional loads encountered in the PTO drive to present-day implements vary tremendously depending upon the individual operating conditions; and, also the potential instantaneous torque available at the tractor is so high that the torque transmitted by the PTO must be controlled primarily by a suitable protective device in the drive if mechanical failure due to torsional overload is to be averted. Since any make or model of tractor is expected to operate any make of implement, the torsional characteristics of the protective coupling are as important to the industry as are the dimensional specifications now established in ASAE and SAE Standards. It is the aim of all tractor manufacturers to extend the use-

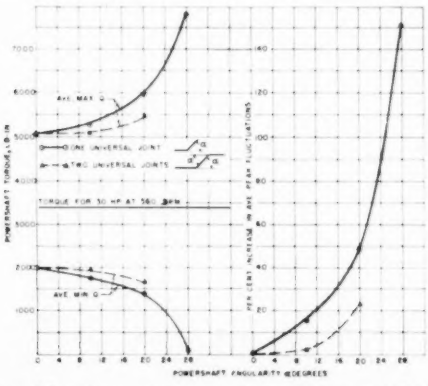

Fig. 4. Effect of power-shaft, universal-joint angularity at 50-hp load.

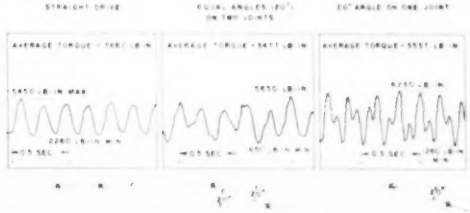

Fig. 5. Torquemeter charts showing the effect of universal-joint misalignment while transmitting an average load of approximately 50 hp.

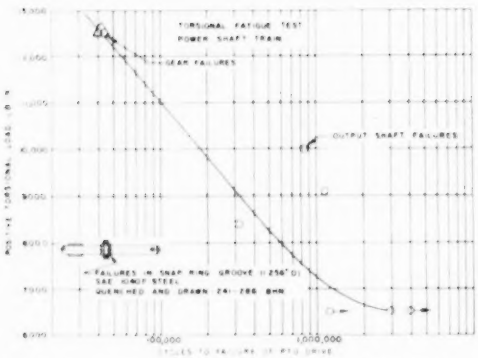

Fig. 6. Torsional fatigue test on a representative PTO drive

tulness of the PTO drive of their tractors as much as possible. Further, no implement builder intentionally wishes to produce a tool which will earn a reputation in the trade of being responsible for causing tractor PTO-drive failures. Establishing realistic torsional load limitations will give both the tractor manufacturer and the implement manufacturer a goal to work toward.

3. Individual implement builders will find that a study of the PTO load characteristics encountered in their implements will often prove very beneficial although the implement may not be an offender from the standpoint of causing tractor PTO-drive failures. Such a study can easily be responsible for correcting conditions of torsional vibration or unnecessarily high torsional loads and thereby improve the performance of the implement as well as reduce the load on the tractor PTO drive.

4. Many implements will be able to use protective devices which limit power-line loads to torsional values below the infinite fatigue life of the present-day standard 1⅜ ASAE-SAE PTO shaft. It does not appear, however, that satisfactory field performance can be secured on some implements with a protective device set this low. Torsional values of approximately twice the infinite fatigue life can be transmitted successfully if they do not occur too frequently. There are many present-day implements that are taking advantage of this characteristic. Obviously a protective device cannot be expected to protect an implement against loads equal to the infinite fatigue life specification and at the same time permit occasional torsional loads of twice that value. In these cases the protective device must protect the drive against the limit established for occasional loads, and then the implement builder must check his implement carefully to insure that it is free from high-frequency torsional loads which exceed the established infinite life figures.

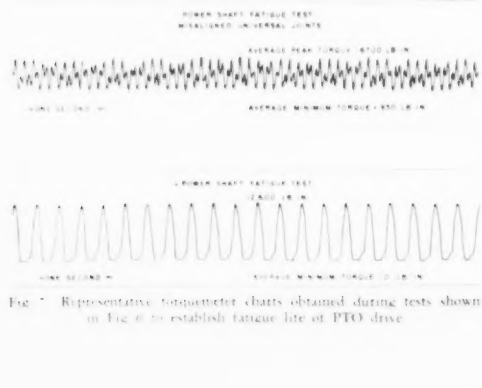

Fig. 7. Representative torquemeter charts obtained during tests shown in Fig. 6 to establish fatigue life of PTO drive

A Study of Power-Take-Off Drives

PROGRESS REPORT

By T. H. Morrell

THE use of power-take-off-driven machines has become increasingly greater during the last fifteen years. This is because of circumstances during that era in which machines such as combines, balers, field silage harvesters and stalk cutters became more common on the farm. The introduction of these machines has pointed toward the desirability of an independently controlled power take-off. Because of the lack of such a device, many farmers were equipping these machines with individual power units. The main reason was to provide for a means of stopping the ground travel without interrupting the power to the machine and particularly to those machines which could be frequently clogged. When some of these machines became clogged while using an interrupted power take-off, considerable hand work was required to clear the machine before operation could continue. A study of this problem prompted The Oliver Corp. to introduce the independently controlled power take-off on its new line tractors, the 66, 77, and 88. This device has proven well worth while in the field. The cost of the independently controlled power take-off on a tractor is small compared to equipping each machine with a separate power unit.

Those machines which could be frequently clogged, presented a problem of overloading the power-take-off shaft and universal joints in the power line. Very high starting torques and field operating peak torques are inherent in these machines which have resulted in shaft failures on all types of power take-offs with shafts meeting the standards.

If there is a difference in the frequency of failure between the conventional and the independently controlled power take-off, it is primarily because of operating characteristics. The conventional power take-off receives its power through the tractor main clutch and is not submitted to such high shock loading under normal operation. The operator will naturally engage a tractor main clutch slowly for smooth tractor take-off which also gradually picks up the load of the propelled machine. This considerably reduces the torque required to set the drawn machine into motion.

A review of what can and does happen with an independently controlled power take-off with its own separate clutch is of interest. First of all, the operator receives no bodily shock when he rapidly engages the separate clutch in the power take-off unit. When this occurs, the maximum starting torque of the propelled machine must be transmitted through the power-take-off shaft which can be several times the maximum output of the engine unless adequate protection is provided. The engine flywheel inertia plays a large part in the transmission of high momentary starting torque. Even when the tractor and machine are being transported and the power-take-off clutch is rapidly engaged, the flywheel inertia is still present and the movement of the tractor and machine can afford more inertia. Let us consider a flywheel running at several hundred revolutions per minute. If we attempt to lock it or stop it quickly, something has to act as a compensator. On first thought one might ask why the power take-off clutch doesn't slip and act as the compensator. The rapid engagement of an overcenter-type clutch somewhat parallels flywheel inertia and under these circumstances a torque value considerably higher than the capacity of the clutch is obtained momentarily until the clutch can break away and start slipping. There appears to be a small margin between having sufficient clutch capacity to carry the loads of normal field operation without clutch failure and sufficiently low capacity to protect the shafts.

(Continued on page 74)

Progress report presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1951, as a contribution of the Power and Machinery Division.

The author T. H. MORRELL, chief engineer, The Oliver Corp., Charles City, Iowa.

Depth and Spacing for Drain Laterals as Computed from Core-Sample Permeability Measurements

By Phelps Walker
ASSOCIATE MEMBER ASAE

THERE is still a great need for basic information upon which to design drainage systems. Engineers and soil scientists have learned much about the movement of soil water and the mechanics of constructing drainage systems, but the coordination of these two factors is dependent at present upon personal experience and judgment.

Considerable work has been done on methods of measuring soil permeability and other soil characteristics such as particle size and clay content. Several attempts have been made to use these characteristics as criteria for determining the depth and spacing for drain laterals (1, 4, 5)*. Van Bavel and Kirkham (6) have proposed a method for measuring soil permeability below the water table. Kirkham (2) has analyzed the seepage into drain tubes in soil consisting of not more than two layers of different permeability. While this fundamental research is essential to the advancement of the science of draining soil, the higher mathematics involved make it difficult to apply in the field.

A simplified approach for determining the most efficient depth and spacing for drain laterals was advanced by Aronovici and Donnan (1) and later by Slater (4). This method and the one presented in this paper are being tested in soils of the Southern Atlantic Coastal Plain.

In 1945 a drainage research project was initiated in Virginia which was founded upon the premise that there are certain definite relationships between the soil permeability and the water table drawdown characteristics of respective soil conditions. The procedure was to measure the permeability of the different types of soil, to measure the drawdown characteristics of these soils, and then to determine the relationships between the two.

This paper presents the method that was derived for approximating the most efficient depth and spacing for drain laterals. It discusses the derivation of the formulas, their application, and some of the needs for additional investigation.

GENERAL CONDITIONS AND ASSUMPTIONS

The soil conditions under consideration are illustrated in Fig. 1. Horizontally stratified layers, each of which is homogeneous within itself, are represented. Permeability, K, and porosity, p, are shown for each layer. Drainage facilities, L_1 and L_2, are installed at depth, D, and spacing, S, and, are assumed to extend uniformly through a great distance. They are considered completely permeable throughout the entire length. Therefore, water movement into drains may be considered to lie in planes perpendicular to the axis of the drains.

It is assumed that recession of the water table is due entirely to the removal of water from the soil by drain laterals. It is assumed further that the forces that move the water into drains may be likened to the forces in the tension method for measuring the permeability of soil cores as described by Uhland and O'Neal (5). In other words, hydrostatic water moves to drains under a tension in the non-capillary pores of the soil created by the free exit of water from the lower end of the soil column. The rate of such flow is assumed to be determined by the permeability of the soil layer having the lowest permeability rate in that part of the soil profile through which the water passes. Then it follows that regardless of the actual path that the water may take through the several soil layers, the resultant lies along radii originating from the respective drains.

DERIVATION OF FORMULAS

The analysis of the problem is illustrated in Fig. 2. The velocity of the water movement resultant, V_1, along a radius through a unit area of soil between point x_1, y_1 on Curve 1 and drain lateral, L_1, is taken to be approximately uniform over a 24-hr period. Then the water-travel resultant along any radius to L_1 for time, t, is $V_1 t$. If θ_1 is the angle between the vertical and the respective radius on which $V_1 t$ is taken, the water table recession, Δy_1, due to flow to L_1 is $V_1 t \cos \theta_1$.

Likewise, the recession, Δy_2, due to flow to L_2 is $V_2 t \cos \theta_2$.

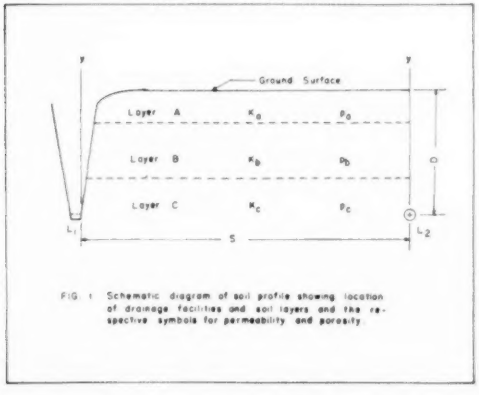

FIG. 1 Schematic diagram of soil profile showing location of drainage facilities and soil layers and the respective symbols for permeability and porosity.

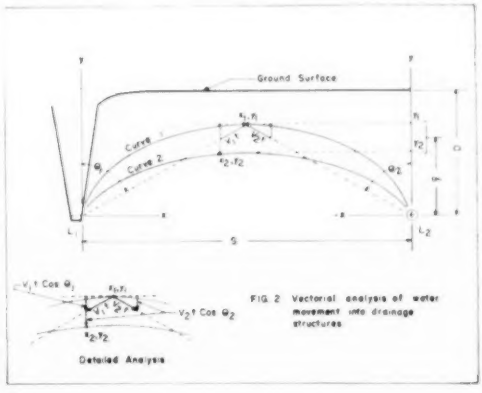

FIG. 2 Vectorial analysis of water movement into drainage structures.

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1951, as a contribution of the Soil and Water Division. It is also a contribution of the ASAE Subcommittee on Depth and Spacing of Tile Drains (Committee on Drainage), and a joint contribution of the Soil Conservation Service, U.S. Department of Agriculture, and the agricultural engineering department of the Virginia Agricultural Experiment Station.

The author: PHELPS WALKER, drainage engineer, Soil Conservation Service, USDA, stationed at Blacksburg, Va.

AUTHOR'S ACKNOWLEDGMENT: The author is indebted to H. N. Holtan, hydraulic engineer, SCS, and W. L. Turner, Jr., soil scientist, SCS Operations, for their assistance in developing this method. He is indebted also to other members of the agricultural engineering department staff of Virginia Polytechnic Institute for their criticism and encouragement in preparing this paper.

*Numbers in parentheses refer to the appended references.

Then the total water table recession, Δy, is

$$\Delta y = \Delta y_1 + \Delta y_2$$

or $$\Delta y = V_{y1} \cos \theta_1 + V_{y2} \cos \theta_2 \quad [1]$$

The permeability, K_1, of the soil layer having the lowest rate in that portion of the soil profile through which water passes to reach L_1 is expressed as rate of movement of a volume of free water. The non-capillary porosity, p, of the soil layer *in which the phreatic surface occurs* is expressed as volume of water per unit volume of soil. Since computations deal with unit volumes, p may be expressed in per cent only. Therefore, the velocity of transmission, V_y, of water toward L_1 is the length of soil column, of unit cross-section area, required to accomodate K_1 volume of water per unit of time

$$V_{y1} = K_1 / p \quad [2]$$

Likewise, the velocity, V_y, of transmission of water toward L_2 is

$$V_{y2} = K_2 / p \quad [2\text{-A}]$$

By substitution, equation 1 becomes

$$\Delta y = K_1 t \cos \theta_1 / p + K_2 t \cos \theta_2 / p \quad [3]$$

Visualize Fig. 1 superimposed on Fig. 2. Since drains L_1 and L_2 are located at approximately the same depth and relative elevation, $K_1 = K_2 = K$. Take point x_1, y_1 at the midpoint on the drawdown curve between laterals L_1 and L_2 or $x_1 = S/2$. Then $\theta_1 = \theta_2 = \theta$.

By substitution, equation 3 becomes

$$\Delta y = 2Kt \cos \theta / p \quad [4]$$

or $$\cos \theta = \Delta y p / 2Kt \quad [5]$$

When Δy is taken as the minimum water table recession increment that permits satisfactory plant growth, then θ is the maximum angle between the vertical and the radius that passes through the midpoint or crest of the drawdown curve.

Let conj y* be the difference in elevation between the midpoint in Δy and lateral L_1. As shown in Fig. 2, conj y is expressed as $\text{conj } y = (y_1 + y_2)/2$

It follows that the horizontal distance from L_1 to the midpoint on the drawdown curve, $S/2$, is conj y times the tangent of angle θ. Mathematically it is

$$S/2 = \text{conj } y \tan \theta \quad [6]$$

and the total lateral spacing between drains is

$$S = 2 \text{ conj } y \tan \theta \quad [7]$$

Frequently drains are installed in soils in which the layer stratifications are not horizontal. Therefore, drains of the same elevation are located in soil layers of different permeabilities, or K_1 does not equal K_2. Then, solving from equation 3, equation 5 becomes

$$\cos \theta = \Delta y p / t (K_1 + K_2) \quad [8]$$

When it is desirable to install drains at varying elevations as shown in Fig. 3, it is necessary to determine θ_1 and θ_2 graphically for several estimated spacings and solve equation 3 with θ_2 expressed in terms of θ_1.

APPLICATION OF FORMULAS

Standard engineering data, soil permeability, soil porosity and rate of water table fall are all that is required to solve equations 5 and 7.

Neal (3) observed that hydrostatic water should not rise to within 6 in of the ground surface. Also, he suggests that free water should recede through the second 6-in increment of soil at the rate of 1 ft per day and through the third 6-in increment at the rate of 0.7 ft per day. While these observations have not been proven by organized investigation, the recession rate of 0.7 ft per day seems to satisfy most conditions.

*Conj y is used in lieu of $\bar{y}$ for to conform to ASA standards for mathematical symbols.

Uhland and O'Neal (5) have outlined the soil core method for measuring the soil permeability which is being used extensively. From these determinations, the permeability and corresponding soil porosities may be obtained for each layer of the soil profile.

The use of the formulas can be clarified further through the following examples from two Virginia soils. The minimum permeability at depths of 2.5 and 3.5 ft and the respective soil porosities of the 1 and 1.5-ft soil layers for the two soils are given in Table 1. The solutions to equations 5 and 7 are listed in Table 2.

TABLE 1. Summary of Permeability Measurements for Lenoir Fine Sandy Loam and Moyock Loamy Fine Sand

Soil type	Lenoir fsl	Moyock lfs
Code	2S32d3	21GQd3
Minimum permeability in top 2.5 ft	0.67 iph or 1.34 fpd	0.80 iph or 1.60 fpd
Minimum permeability in next foot (to 3.5 ft)	0.23 iph or 0.46 fpd	0.63 iph or 1.26 fpd
Porosity between 1.0 ft and 1.5 ft depth	9.4 per cent	13.2 per cent

From the results in Table 2, it seems that the most economical drainage system in Lenoir fine sandy loam should be designed with a lateral spacing of 90 to 100 ft at a depth of about 2.5 ft. In Moyock loamy fine sand, on the other hand, the 37 ft additional lateral spacing justifies the extra cost of excavation and drains should be located at 120-ft spacing and an approximate depth of 3.5 ft.

TABLE 2. Computation for Determining the Most Suitable Depth and Spacing for Drain Laterals

Soil type	Lenoir fine sandy loam		Moyock loamy fine sand	
Code	2S32d3		21GQd3	
Depth of drain from ground surface, ft	2.5	3.5	2.5	3.5
Recession increment per day, Δy, ft	0.7	0.7	0.7	0.7
Porosity x unit volume, p	0.094	0.094	0.132	0.132
Time interval, t days	1	1	1	1
Minimum permeability, K fpd	1.34	46	1.60	1.26
$\cos \theta = \Delta y p / 2Kt$	0.024355	0.071752	0.028888	0.036667
Tan θ	43.92	13.93	34.61	27.25
Average depth to drain, conj $y = (y_1 + y_2)/2$	1.2 ft	2.2 ft	1.2 ft	2.2 ft
Spacing, $S = 2$ conj y tan θ	98.2 ft	61.4 ft	83.1 ft	120.0 ft

NEEDS FOR ADDITIONAL RESEARCH

There are several factors that need further investigation.

Accuracy. In setting up this method for determining the spacing for drain laterals, it is recognized that assumptions

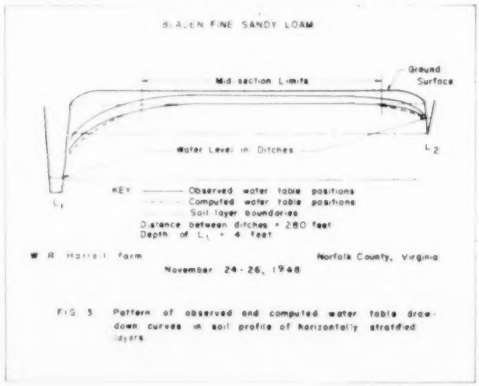

FIG. 3. Pattern of observed and computed water table drawdown curves in soil profile of horizontally stratified layers.

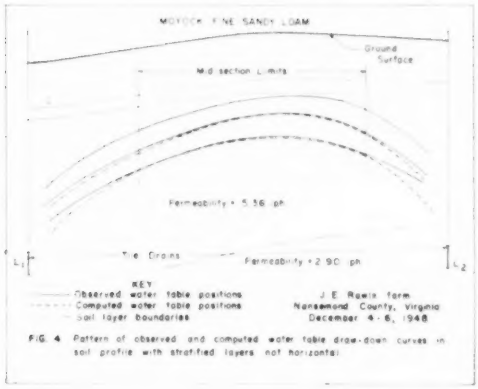

FIG. 4. Pattern of observed and computed water table draw-down curves in soil profile with stratified layers not horizontal.

have been made to meet practical requirements. However, after reviewing a large number of observed and computed water-table drawdown curves like those shown in Figs. 3 and 4, and noting the similarity of pattern for curves in both horizontally and obliquely stratified soils, the method appears applicable to most soil conditions tested. The limits within which these curves are congruent is called "midsection limits." The extent of the midsection limits seems to vary in different soil conditions. Additional research is necessary to determine the factors responsible for this variation between the limits and their effect upon the accuracy of the method.

Variations in Permeability and Porosity Measurements. Perhaps the greatest cause for concern lies in the wide variation between replicate soil permeability and porosity measurements. The results of Lenoir very fine sandy loam given in Table 3 are characteristic of many determinations made in Virginia. Although the average data when used in equations 5 and 7 give results that are in agreement with the estimates of experienced field engineers, the range of permeability values from 0.02 to 0.21 iph raises the question of what is the actual permeability of this soil. The same question is true for the soil porosity measurements.

TABLE 3. Soil Permeability and Non-Capillary Porosity for Several Determinations in Lenoir Very Fine Sandy Loam (Code 2M21d5)

Site number	Minimum permeability at 5.5 ft	Non-capillary porosity at 1.5 ft
16	0.02 iph	4.6 per cent
17	0.21	10.4
20	0.12	7.6
242	0.12	6.9
Average	0.12	7.4

There is a need for additional information on soil-water movement which should be secured readily from additional tests while making permeability determinations. Most of the present routine laboratory measurements are conducted under constant heads and tensions (5). According to the concept of the method presented in this paper, the tension drawing water to drains decreases as the water table recedes. Therefore, tests should be included in the laboratory procedure which will determine the effect of varying tension on percolation rates and porosity measurements.

Water Supply and Depletion. No attempt was made to develop the method to suit either artesian or deep seepage conditions. However, if the rate of supply for artesian conditions or depletion due to deep seepage is determined, it seems likely that the formulas can be modified to make the method applicable to these conditions.

CONCLUSIONS AND SUMMARY

This paper presents a method for approximating the most efficient depth and spacing of drain laterals computed from permeability measurements. Where adequate permeability measurements are available, the method seems to be satisfactory in most of the soil conditions encountered in Virginia. It is designed to take into account soils composed of several layers of varying permeabilities and porosities. It is equally applicable when drains are located in different layers as long as the drains are at approximately the same elevation and equal depth. While the method is still applicable, it is more difficult to apply when the elevation of the respective drains vary considerably.

Refinement of the method is desirable. Investigation should be conducted to determine the limits of the midsection and if these limits are ever too small for the formulas to be satisfactory. Intensive investigation must be conducted to determine what characterizes a representative permeability sample and how to minimize the wide range of variance occurring between replicate measurements. More precise results can be obtained by evaluating the effect on the movement of soil water of varying tension and natural water supply and depletion factors.

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A Study of Power-Take-Off Drives

(Continued from page 70)

Because of the power-take-off-shaft failures within the farm equipment industry, a special subcommittee of the Advisory Engineering Committee of the Farm Equipment Institute was set up to study the problem. On May 31, 1950, the subcommittee met and reviewed the existing ASAE-SAE power take-off standard. It was recognized that an expansion of the standard should be made to include the lateral location of the hitch point with respect to the power-take-off shaft and to include standards on the power line between the tractor and the implement. It was decided at that time that each interested company should gather all data relating to the problem with respect to the type of machine causing failure, tractor model, type of failure and operating conditions; also, that each company should do everything possible in the form of bulletins, instruction manuals and decals to stress the importance of correct power line installation within the limits of existing designs.

Subsequent meetings of this subcommittee were devoted primarily to the imposed loads on power take-off shafts and of a study of various operating conditions. It was decided to make no changes in the existing standard as far as the tractor was concerned, if the problem could be solved otherwise. The thought is that a torque-limiting device on the propelled machine or in the power line should be provided and that the limiting torque should be determined by tests with each company making its recommendations.

Although no definite conclusions have been reached to solve the problem of power-take-off-shaft failures, the operating characteristics of numerous propelled machines and tractors which have been determined through an industry-wide study are of great interest and valuable for future designs.

Heat Transfers in Citrus Orchards Using Wind Machines for Frost Protection

By F. A. Brooks, C. F. Kelly, D. G. Rhoades, and H. B. Schultz
FELLOW ASAE MEMBER ASAE

FROST protection may seem contrary to nature, but artificial efforts do little more than supplement natural heat sources which by themselves do not quite keep the minimum temperature above the danger point. Such extra help is worth an average expenditure of over a million dollars per year for citrus growers in California because this subtropical fruit is purposely grown where subject to moderate winter chill. Thus our objective is to minimize frost damage in a region naturally subject to light winter frosts. Frost protection practice, though described in Roman times, did not develop in California until Floyd Young (1947) organized the Weather Bureau Fruit Frost Warning Service over 40 years ago. The University of California studies were initiated about 10 years later by Schoonover (1925, 1932, 1939) and since the double freeze of 1937 have been carried on intensively by the Division of Agricultural Engineering. Leonard (1950) made an important contribution to this project 10 years ago, developing a virtually smokeless heater by diluting the fuel vapor in the bowl. This return-stack heater*, available to growers for $6, is so good it is sold extensively at $15 as a space heater for garages and warehouses.

Major freezes, which are publicized by reports of millions of dollars of loss, come in southern California only when a strong outburst of polar continental air is preserved by extensive snow cover and subzero temperatures in Nevada. Naturally in a freezing wind it is not possible to prevent losses. The areas hit worst vary from freeze to freeze, and the "best" locations for ordinary calm radiation frosts often suffer more in the wind than do sheltered "cold pockets." With this erratic damage pattern nobody expects *complete* frost protection without enclosure. On the other hand, complete loss is rare unless orchard temperatures go below about 20 F.

Ordinary radiation frosts on calm clear nights have rather consistent distribution, with warm air overhead, the main irregularity being the velocity of the cold-air drainage. Higher land is generally more free from frost and is preferred for lemon orchards, for which critical temperatures are about 2 F higher than for oranges.

The frost protection problem is therefore double-faced: (1) moderation of freeze losses in occasional bad years and (2) economical protection from typical radiation frosts several nights every winter. One grower expresses it thus: "I expect to lose my shirt every seven years, but I want to stay in business the other six."

Fig. 1 shows two of the modern large wind machines erected side by side for comparative tests at the University of California citrus experiment station at Riverside. The whole tower top rotates slowly, bringing a blast to a given direction every 4 or 5 min. The propellers are mounted 32 ft above ground and directed slightly downward so that the air blast penetrates the orchard about 80 ft away and produces strong low-level gusts from about 150 to 300 ft. The single electric 90-bhp machine is specially designed for downdrift operation, taking 4 min to sweep the lower 180 deg but skipping around the updrift 180 deg in 1½ min. The dual-engine machine, each operating at 65 bhp, turns 15 deg per min, as is usual for square 15-acre tracts. The system at Oxnard (Brooks, 1948, Citrus Leaves) produced a 2 to 4 F general response, and a cyclic 1 F blast response of a lemon on the outside edge of tree foliage at a distance of 250 ft from the machine. Fig. 2 is a view of the Rewald orchard near San Bernardino showing, beyond the road, protection by wind machines alone, increasing from right to left in the direction of air drift.

Economic Aspects of Frost Protection. With heating costs now about 2 times as expensive as before World War II, and with no appreciable rise in fruit price due to a freeze, some growers who profited by frost protection 50 years ago cannot

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*The Return-Stack Orchard Heater by A. S. Leonard, AGRICULTURAL ENGINEERING, vol. 32, pp. 655-656, 664-664 (December, 1951).

SUBSCRIPTS

b = border	*op* = protected orchard
d = dew	*r* = sky radiation
dp = dew point	*s* = soil
g = gravity flow (air drift)	*se* = soil evaporation
i = initial condition	*su* = surface
o = orchard trees	*z* = air at tree top

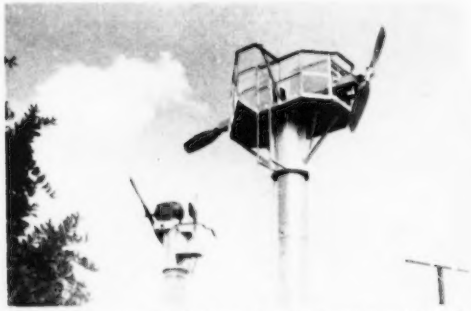

Fig. 1. Single electric and dual-engine wind machines installed side by side for comparative tests. Towers 32 ft high, upper part revolves bringing direct blast every 4 or 5 min to trees 80 ft away and strong gusts from about 150 to 300 ft.

Fig. 2. Protection afforded by wind machines in orchard exposed to cold air drift from the right, near San Bernardino, Calif. Dark area unharmed; light area badly frosted, extending updrift in a wedge-shaped triangle from oil-storage tanks; spot of frost damage at base of nearest machine

now afford to use installed equipment even though its capital cost was written off long ago. The difficulty is that the cost of frost protection goes by the acre, but the net income to pay for it comes only from the fruit *saved*. Therefore, the economic value of frost protection depends directly upon the productivity of the orchard in quantity and quality. No close averages can be stated, but the general opinion is that the grower who has to heat more than 6 or 7 nights per year is probably losing money on that operation.

Knowledge that citrus fruit loss is not suddenly devastating at a certain critical air temperature, caution in using high-cost fuel, and worry over the public anger at the smoke from heaters have led many growers to delay firing them until the more exposed fruit has actually frozen. Considering high heating costs and the postwar acceptance of partial loss, the limitations of wind machines now seem less objectionable and their low operating costs very advantageous.

Frost protection by wind machines, economical by virtue of redistributing the warm air usually found above tree tops, came into use over 30 years ago (Moses, 1938). Although not affording reliable protection, their use continued and has greatly expanded since the War, largely because the operating cost is about 1/5 that for heaters. Field studies of carefully recorded expenditures for frost protection using heaters and wind machines reported by Yarick (1950) for Los Angeles County show heating to cost about $3.60 per acre-hour; wind machines alone, $0.55; and a combination of wind-machines plus heaters about $0.67 per acre-hour, the wind machines running about 100 hr per season.

When the 2 or 3 F temperature rise obtained by machine under ordinary conditions is not sufficient, the firing of 8 to 15 heaters per acre (instead of 25 to 50) usually supplies an extra degree or two, and failure to maintain "safe" temperatures seems to have resulted in less loss than anticipated in quiet air. Thus the *combination* of machine and heaters meets the usual radiation frost conditions in California so well it is now the accepted system for economical frost protection. The approximate investment cost for the combination is now about $100 an acre.

According to recent economic studies (Adams, 1951), there are in California now more than 2,800 wind machines, 2000 which are 70 hp or more. All types together represent an investment by growers of over $8,000,000 in mechanical means of frost protection. Four million heaters are still in citrus orchards, but there are antismoke ordinances in most areas requiring elimination of smoky types.

The general conclusions of the report on costs versus benefits are that the basic terms in the cost balance equation are: (1) quantity and quality of product per acre, (2) frequency and severity of damaging frosts, and (3) cost per degree temperature rise obtained by artificial protection. Naturally the statistical determination of weather hazard is part of the agricultural engineer's duty, but this paper is directed to basic heat transfer problems, keeping in mind that efficient use of natural heat sources will yield the most economical results.

The simultaneous interaction of multiple heat exchanges acting through thermal resistances which vary with depth, and even with gradient (as in stable air), may seem impossible to understand in a quantitative sense. We can proceed confidently, however, into any complex heat-exchange problem if the rates of flow by each of the three or four modes of heat transfer can be measured or determined. Before describing the response curves for the modified heat-transfer system in typical orchards, we will, therefore, first consider the fundamental action of each mode of heat transfer and its relation to the whole, natural complex during radiation frost on a calm, clear night, in a flat orchard area so extensive that border conditions can be neglected.

RADIATION COOLING TO THE COLD SKY

If there was no atmosphere, the radiation cooling to cold space would be so excessive we would have frost every night. An example of this is seen in the measurements by Pettit and Nicholson (1930) of the surface temperature of the moon during an eclipse. They found a change from plus 160 F to minus 150 F in two hours! This happens to be almost independent of heat stored in the solid because of the low thermal conductivity of dust on the surface. On the earth in the same exposure in sunshine and cold space, without the atmosphere, the nocturnal cooling rate before sunrise would be about 5 F per hr instead of the observed average 1 F. This is because the outgoing radiation loss from a surface is reduced about 4 to 1 by the downward radiation from the atmosphere. Thus the earth's atmosphere, as an extensive heat source radiating back to the ground, restricts typical radiation frosts in citrus areas to those few calm clear nights having cold or dry atmosphere aloft.

Reduction of Radiation Loss by Clouds. The frost warnings are always qualified with a proviso of no cloudiness (other than cirrus) because a water-droplet cloud acts as a radiation shield and when at low level itself radiates at a temperature not much colder than the daytime air temperature. Radiometer observations on the night of January 12, 1939, Riverside, showed clearly the sudden stopping of radiation cooling by clouds. They showed also that coincidently the surface ground temperature rises when the previous temperature gradient, developed to provide full radiation loss, is no longer needed to meet the lessened net radiation demand of the sky. Another example of radiation screening by an overhead fog was observed near Strathmore (east of Tulare in the central California citrus district) on February 11, 1939. The sky was clear at 11 p.m. From 2:40 to 3:00 a.m., radiation measurements indicated clear-sky conditions although the stars were not very bright. Then a low, wet, overhead fog came in and radiation loss virtually ended. This cloud was seen, by searchlight and the captive balloon, to occupy a layer 200 ft thick extending from 50 to 250 ft above the ground.

Advance Measurement of Nocturnal Radiation Loss Rate. Depending on the character of the air mass, there can be considerable difference in net radiation loss ranging from 15 to 25 Btu/hr ft². The observed rate of net radiation on a given night, however, is usually fairly steady, diminishing so slowly after midnight that, in general, it can be assumed substantially constant as long as the sky remains clear. The magnitude of this steady net radiation rate is measurable after dark by an uncovered hemispherical radiometer if the sky is entirely clear (except for cirrus). Such measurements can be rendered virtually independent of the higher evening temperatures by interpretation as fractional transmissivity. When a radiometer is not available, the transmissivity for clear nights can be calculated if the total precipitable water in the atmosphere is known (Brooks, 1952); or the approximate net radiation loss can be estimated by variations of Angstroms' formula from surface observations of moisture and temperature (Brunt, 1939, and Geiger, 1950).

Expression of Radiation Loss Rate for Estimating Hourly Cooling. Most conveniently for the concept of progressive decrease in temperature at night, the net radiation, E_{ru}, can be interpreted approximately in terms of the difference between tree-top temperature and equivalent sky temperature, namely

$$-E_{ru} = -\varepsilon h_{rb} (t_u - t_r), \quad (B/hr\,ft^2) \qquad (1)$$

where $h_{rb} = \sigma (T_u + T_r)(T_u^2 + T_r^2)$, which is substantially constant.

The continual heat outflow by radiation to the night sky is in fact an irresistable heat demand on all exposed surfaces as an opposite to solar energy received throughout the daytime. Consequently during the night every square foot of surface — trees, grass, or bare ground — must continually be giving off heat received from terrestrial sources which are somehow connected thermally with the radiating surfaces. These sources are primarily: the ground; the air above the trees; water vapor condensed and frozen within the orchard; the heat capacity of the orchard trees and air, and, finally, if there is artificial heating, the heat of combustion of fuels. Heat of respiration is virtually non-existent because of low temperatures at night.

HEAT FLOW BY CONDUCTION FROM THE GROUND

Next in importance for nocturnal heat balance in the orchard is the heat flow from the ground, as the ground is the major source of supply for heat radiated to the sky. Fortunately this soil heat loss can be directly measured by a heat-flow plate just under the soil surface. Careful heat exchange measurements made over very smooth, hard ground in the joint project reported by Vehrencamp (1951) shows that in this case (with deep ground temperatures high, relative to a fresh cold air mass) the ground heat supplied 80 per cent of the net radiation loss at the beginning of the night, and substantially all of it before sunrise when the temperature difference between ground surface and air at 80 in was almost zero.

To determine the effect of soil moisture on the diurnal cycles of temperature and soil heat flow, test plots of 5 acres each were studied in a pear orchard near Lakeport, Calif. Two plots were disk-cultivated, and one of these was immediately flood-irrigated lightly. The observed doubling of heat-flow rates and sharp decrease in daytime temperature might have been anticipated for the increase in thermal conductivity of the moist soil. The evaporation chill of 7 F was, however, much more than expected. The watered plot took more than 10 days to recover. In 14 days it had warmed up to a higher temperature than the unwatered plots and then provided some frost protection.

Advance Measurement of Soil Heat Source Temperatures and Soil Heat Flow. More easily than for radiation, the all-important starting temperature levels of the ground, the air, and the trees can be measured before nightfall. In these cases it is best to use the temperatures relating most closely to the average for the stored heat to be drawn upon during the night. For soil heat this should be, not an air temperature 50 or 60 in above ground, but some soil temperature. The 4-in-depth temperature is chosen here as the average for the heat drawn, because from the measurements reported in Fig. 3 it is seen that there is very little diurnal temperature change below 12 in.

To deliver the stored heat from the soil, temperature gradients become established to the degree necessary to meet the heat demand. This demand may be less than the radiation loss with some heat coming from the air by eddy convection, or the soil heat flow can exceed the radiation loss in very quiet air when additional heat is required for evaporation at the soil surface. In all cases, therefore, at night the loss of soil heat makes the surface colder than the heat-source temperature deeper in the ground, and it is the degree of this drop in surface temperature which limits the frost hazard in the orchard.

Expression of Soil Heat Conduction for Estimating Hourly Cooling. The basic heat conduction equation is

$$E_s = -k\left(\frac{dt}{dz}\right)_s, \qquad (B/hr ft^2) \qquad [2]$$

This heat rate is directly measurable by plate heat-flow meters. Judging by slopes in Fig. 3, the gradient dt/dz is practically constant on clear calm nights from midnight to 6 a.m. in February. Furthermore, since the gradient is nearly linear in the upper few inches, it can be evaluated if soil temperatures are measured near the surface and at 2 to 4 in deep. Thus thermal conductivity of the soil can be determined in situ from the measurements of heat flow E_s, and of soil temperature at two depths.

Although the soil is never a homogeneous substance with uniform thermal characteristics throughout, the ground as a solid of considerable heat capacity reacts to a steady heat loss very much as would a semi-infinite slab. It is useful therefore to adopt the temperature solution given by Jakob (1949), if it is modified by an empirical coefficient, C_s, to include the extra hours of cooling because evening temperatures near the surface exceed the uniform (deep) temperature assumed for the idealized analytical system (see 6 p.m. profile Fig. 3).

The temperature decrease at the surface, $z = o$, can then be expressed as

$$\Delta t_s = 2C_s\left(\frac{dt}{dz}\right)_s \sqrt{\frac{\alpha\theta}{\pi}}, \qquad (deg.\ F) \qquad [3]$$

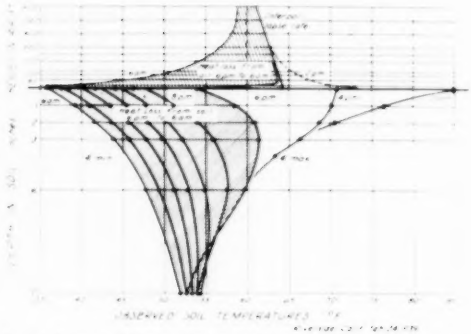

Fig. 3. Rate of nocturnal heat loss from soil and air, as indicated by drop in temperatures, at 2 hr intervals. The depth in soil is plotted at a ratio of 1500 to 1 as compared to the height in air, so that the shaded areas indicate the same heat capacity per unit area. About four times as much heat is lost from the ground as from the air during typical radiation frost night, and most of the ground heat comes from the upper 6 in, very little below 12 in.

This is the basic concept of surface cooling until the time of starting heaters for frost protection. Inasmuch as the temperature gradient at the surface is constant for steady heat loss, equation [3] shows that surface temperature would decrease as the square root of time, θ, since the start of sudden radiation when the whole slab was at uniform temperature $\Delta t = 0$. Also for infinite time (or $z/\sqrt{\theta}$ very small), the temperature increases linearly with depth. The temperature drop does not increase with diffusivity, α, as might seem indicated, because the corresponding increase in conductivity would decrease the gradient for a given heat-flow rate.

Equation [3], relating temperature gradient to hours of cooling, provides a means for using the observed soil heat flow, E_s, as expressed in equation [2], to estimate the hour-by-hour temperature drop. It is desirable, therefore, to express the heat-flow rate from the soil, under steady loss conditions in terms of temperature decrease and time, namely

$$E_s = -c_s k\left(\frac{dt}{dz}\right)_s = \frac{c_s k(\Delta t)_s}{2C_s\sqrt{\frac{\alpha_s\theta}{\pi}}}$$

$$= \frac{c_s k}{2C_s\sqrt{\alpha_s\theta/\pi}}\ (t_i - t_{su})\ soil, \qquad (B/hr ft^2) \qquad [4]$$

HEAT FLOW BY CONVECTION FROM THE AIR OVERHEAD

The nocturnal heat flow from overhead air by eddy convection downward follows much the same pattern as heat flow from the ground. Because of daytime heating, the air from 100 ft above ground to a few thousand feet is usually more than 20 F above freezing. Thus if there is powerful eddy convection, as in a wind, so much heat is available from such a huge depth of air that ordinarily there is no frost hazard. And, conversely, on very calm nights of excessive stability, there is very little eddy convection, and a thin layer of air near the ground quickly drops in temperature because of the inherently small heat capacity of air. Naturally the air heat supplements the ground heat in meeting the net sky radiation demand, so that a high thermal conductivity for one automatically decreases the temperature gradient needed in the other. This is most easily visualized in the combined Fig. 3. Ordinarily in sheltered southern California citrus areas during radiation frosts, the air by convection and short-range radiation will furnish only 20 to 25 per cent as much heat to the cold sky as the ground does. If wind machines change the natural eddy-convection rates overhead, the air-heat contribution might be increased artificially, but their effect on downward eddy thermal convection from overhead air has yet to be calculated.

Advance Measurement of Overhead Air Heat Source Temperature. The basic air temperature is the meteorological or lapse-rate temperature maximum preferably observed at 50 ft above ground or higher. Afternoon air temperatures closer to the ground are usually in a superadiabatic layer where high temperatures collapse with the ending of sunshine.

At night as the soil surface temperature drops (because of losing heat by radiation to the cold sky), it develops an increasing temperature difference relative to the air overhead, establishing a potential to drive heat from the air toward the ground (see upper part of Fig. 5). Although it is easy to measure this temperature gradient, we still do not know the rate of heat flow downward because we have no way of measuring eddy heat flow nor the eddy conductivity of the stable air. We know only the minimum — the molecular conductivity of air — which is about one-third that of corl. Daytime eddy conductivities may run 1000 times the molecular, and because of the frictional shear even in stable air, there must be some eddy conductivity, which might be interpretable from the observed shear stress under very smooth flow. (Vehrencamp, 1951) and knowledge of variation of eddy diffusion with air stability (in Brooks, June, 1947). In a similar recent treatment, Reuter (1947) seems to use the observed vertical extent of the nocturnal inversion to determine an over-all eddy conductivity of the air. Such procedure includes short-range radiation cooling of the air, for which the observed net radiation should be corrected upward.

Expression of Overhead Air Heat Convection for Estimating Hourly Cooling. As soon as the eddy conductivity for stable air can be evaluated, formula (3) can be applied as first approximation for the cooling of the air, and similar to formula (4) the equation for air heat transfer downward, E_u, could be

$$E_u = c_s K \left(\frac{\partial t}{\partial z}\right)_u = \frac{c_s K \Delta t_u}{2C\sqrt{\sigma_u \theta/\pi}}$$

$$= \frac{c_s K}{2C_u\sqrt{\sigma_u \theta/\pi}} (t_t - t_u)_{air}, \quad (B/hr ft^2) \qquad [5]$$

Combined Soil and Air Heat Transfer Relationships at Bare-Ground Surface During Nocturnal Radiation Cooling. Under the observed net radiation loss, which was practically constant, and considering heat from the soil and air as supplying the entire radiation demand at the surface, the diagram Fig. 5 shows the nocturnal sweep of soil temperatures according to measurements at Riverside in 1939, and the corresponding air-temperature profiles interpreted for bare ground from measurements from 20 to 60 ft and interpolated radiosonde data. The ordinate scales for air and soil are chosen 1500 to 1 to represent graphically the same heat capacity; thus the shaded areas represent the proportional heat sources for the total radiated to the sky during the night. A large part of the heat lost by the air is by short-distance, atmospheric radiation, which is part of the measured back radiation leading to the fractional net radiation loss, E_{nr}. The part of the air heat coming by eddy convection is therefore less than indicated by the shading; for the Riverside example it amounts to about one-fifth that given up by the soil. The progressive crowding of the 2-hr temperature profiles is to be expected for interpreting soil surface temperature versus time by the square-root law (equation (3)). This bare-ground exchange is, of course, too simple for an orchard, but the concept of Fig. 5 can be expanded by lifting the air interface to tree-top level. Because of radiation loss from foliage to cold sky the air at tree-top level is chilled to nearly the same degree it would be over bare ground; hence hourly cooling curves in Fig. 5 still represent approximately what happens at the bottom and top of an orchard. The essential difference is the introduction of a heat source because of the heat capacity of the trees and orchard air.

HEAT AVAILABLE FROM HEAT CAPACITY OF TREES AND ORCHARD AIR

The starting temperature of the orchard is not important because the heat capacity of the trees is limited by such a small average size of branch that there is very little time lag in the diurnal temperature waves. Thus the main effect of tree material is the heat made available hour by hour, which saves the soil heat a little. Until we study heat transfer for the leaves, fruit, and cover crop, the excessive complications within the orchard can be evaded by treating the whole depth of the orchard as a block layer whose effective temperature is taken as that of the air in the trees at 2 m (80-in.) height.

Expression of Heat Released by Hourly Cooling of Orchard Trees and Air. The heat released within the orchard air layer by temperature change is found from the heat-capacity formula

$$E_o = c_2 \{-(\gamma c_p w)_{trees} - (\gamma c_p w)_{air}\} \left(\frac{\partial t}{\partial \theta}\right)$$

or for combined trees plus orchard air

$$E_o = -c_2 \gamma c_p w_o \left(\frac{\partial t}{\partial \theta}\right)_{\substack{trees\ and \\ orchard\ air}} =$$

$$c_2 \gamma c_p w_o \left(\frac{t_1 - t_2}{\theta}\right)_{orchard}, \quad (B/hr ft^2) \qquad [6]$$

While cooling 1 F per hr a 9-year-old orchard provides about 10 per cent of the radiation demand, and since this will increase with tree weight it may be the significant reason for older orchards being less susceptible to frost damage.

NOCTURNAL HEAT FROM CONDENSATION AND FREEZING OF MOISTURE

Change of phase of moisture is often a noticeable source of nocturnal heat. The rate of hourly cooling is usually slow and steady on a night of high dewpoint, and there is often a dwell of a half hour or more at 32 F, whereas in a black frost the temperatures usually drop rapidly and are unsteady. The slower cooling is due mostly to increased back radiation from the more moist atmosphere. The temperature steadiness in the moist air is largely due to stronger water vapor radiation exchange over short distances.

The heat evolved in lowering the dewpoint from, say, 40 to 32 F is only about 8 Btu per sq ft for an air layer 60 ft thick. If this takes 1 hr it is about one-tenth the nocturnal radiation rate. This may mean, however, a 2 or 3 F higher minimum temperature because of the usual 20- to 30 F temperature gradient. In freezing the dew the latent heat is about 1 Btu per horizontal square foot, which is equivalent to 1 F in a total of 20 F gradient. If this occurs in one hour, it counteracts the usual 1 F drop and explains the dwell at 32 F. The heat released by freezing leaves and fruit at lower temperature is excluded as occurring beyond frost protection. Some growers object to starting wind machines above 32 F because they make a drier orchard and the temperature dwell at freezing is not evident. Incidentally, this drying effect leads many growers to keep their machines running several hours after sunrise to promote recovery of partially frozen fruit.

Advance Measurement of Moisture and Expression for Heat Released. The 2 p.m. humidity observation indicates fairly well the moisture conditions for the succeeding night, unless there is a frontal passage bringing a change of air mass. The regular frost warnings always include the evening dewpoint. The moisture problem therefore is difficult only when one tries to determine how much is brought downward from the air by eddy convection. The potential drive, that is, the vapor-pressure gradient, is very difficult to measure unless expensive aspirating, dewpoint automatic recorders are employed. This is needed, however, only for the condensation, which is the minor part of the moisture effect relative to the radiation part.

The heat released by moisture change of phase is

$$E_{H_2O} = (1076\, w_{dew} + 144\, w_{ice})/\theta, \quad (B/hrft^2) \quad [7a]$$

This latent heat acts as a heat source inside the orchard, and since the condensation part comes with decreasing orchard temperature — approximately 1 Btu/60ft F — it is most satisfactory to neglect the smaller, freezing part and restate the moisture equation as

$$E_{dew} = -c_3\, \lambda_t\, w_d \left(\frac{dt}{d\theta}\right)_{orchard\ air} = c_3\, \lambda_t\, w_d \left(\frac{t_{dp} - t_o}{\theta_d}\right)_{orchard,} \quad (B/hrft^2) \quad [7b]$$

Heat Taken Up in Nocturnal Evaporation of Moisture at Soil Surface. With soil temperatures within the first few inches warmer at night than the surface temperature, there is a vapor-pressure gradient driving moisture out of the soil, the soil surface often having a higher dewpoint than air at foliage level where dew is being formed. Evaporation at the soil surface may become significant in the heat-exchange system because of the large latent heat involved. Careful measurements by Dr. S. J. Richards at Riverside, February, 1951, in moist soil showed an average moisture loss in 16 hr of 0.014 lb per sq ft. This is probably high for the acreage as a whole, but in terms of heat rate amounts to 0.8 Btu/hrft², which added about 1 per cent onto the heat lost by net sky radiation. This, with low-level eddy convection upward, probably is the explanation of Chin's (1951) finding more heat flow from the soil than the sky radiation demand. If wind machines increase such evaporation this would be a disadvantage in their operation.

When there is evaporation from a moist surface, a term for heat absorbed is needed, namely

$$E_{se} = c_4 C_e\, \lambda \left(\frac{dw}{d\theta}\right)_{soil\ evap.,} \quad (B/hrft^2) \quad [7c]$$

where C_e is a coefficient including the air influence on soil-moisture evaporation, and c_4 an area-distribution coefficient. There is no simple way of relating the expression with hourly evaporation to hourly cooling, yet all the temperatures and heat rates are so interdependent, a conversion with reasonable accuracy can be made using another empirical coefficient, C_t. This leads to

$$E_{se} = +c_4 C_e C_t\, \lambda \frac{w_{se}}{\theta} (t_i - t_{su})_{soil,} \quad (B/hrft^2) \quad [7d]$$

which can be grouped with the expression (equation [7b]), for dew.

TENTATIVE BALANCE OF NATURAL, NOCTURNAL HEAT RATES IN AN EXTENSIVE ORCHARD

Considering the net radiation demand to be met by heat flows by conduction from the soil, by eddy convection from overhead air, by direct orchard cooling, and by latent heat of moisture change, the heat-rate expressions in equations [1], [2], [5], [6], [7b], and [7c] together make the heat balance for the orchard layer. With appropriate coefficients, the equation for nocturnal heat balance neglecting freezing is therefore

$$E_{ru} = -c_1 \lambda \left(\frac{dt}{dz}\right)_s + c_8 K_g \left(\frac{dt}{dz}\right)_u - c_2\, \delta\, c_p\, w_o \left(\frac{dt}{d\theta}\right)_o - c_3\, \lambda_t\, w_d \left(\frac{dt}{d\theta}\right)_o + c_4 C_e\, \lambda \left(\frac{dw}{d\theta}\right)_{se}. \quad (B/hrft^2) \quad [8]$$

In this expression the orchard heat-capacity term is small and known with fair accuracy when $(dt/d\theta)$ is measured (at 80 in height). The net radiation is measurable and the ground conduction is directly observable if the soil heat-flow meter is located in a spot representative of the whole area. Only the convection term is in doubt, for lack of knowledge of the proper eddy-diffusivity coefficient to use for various degrees of inversion stability and orchard roughness. At present, therefore, equation [8] can be used, not as verification of all the heat transfers by demonstration of heat balance, but to calculate the eddy-diffusivity coefficient which then will lead to a workable understanding of all the transients in nocturnal cooling.

Omitting condensation and evaporation, our present estimation of heat flows inside large citrus orchards for an average outgoing radiation loss of, say, 22 Btu/hrft² ascribes a total of probably 75 per cent from the ground made up of 40 per cent going directly from the exposed soil surface to the sky, another 20 per cent by indirect radiation, and another 15 per cent indirectly by convection currents to the tree tops. Of a total of about 17 per cent from the air, probably 15 per cent comes by eddy convection downward to the radiating surfaces from above the orchard, and 2 per cent by cooling orchard air. Then the cooling of the trees as solids would account for the remaining 8 per cent.

(To be continued in the March issue)

APPENDIX

Symbols and Units

$c_{1,2,3,4}$ (non-dim)	= coefficients to adjust for irregular area distribution
$c_{s,e,u,t}$ (non-dim)	= correction coefficients (functions) for temperature gradients, etc., to adjust local deviations of temperature and thermal properties of the soil, etc., from the over all averages to suit idealized formulas
E, (B/hrft²)	= heat transfer rate (identified by subscripts)
b_{rb}, (B/hr ft² deg F)	= unit radiation conduction (black body) $= \frac{0.173}{100} \frac{(T_1 + T_2)}{(100)} \frac{(T_1^2 + T_2^2)}{(100^2)}$
k, (B/hrft² / (deg F/ft))	= average thermal conductivity of the soil (= 0.? for soil at Riverside, February, 1939)
K, (ft² hr)	= average eddy diffusivity
t, (F)	= temperature, F
Δt, (deg F)	= temperature departure from original uniform magnitude (at any depth, z, and time, θ, since start of irradiation)
$\frac{dt}{dz}$, $\left(\frac{\text{deg F}}{\text{ft}}\right)$	= average temperature gradient vertically in the soil or the air, representing the equivalent homogeneous gradient in depth and time
T, (°R)	= absolute temperature (degrees Rankine)
w, (lb/ft²)	= effective weight of substance per unit ground area
z, (feet)	= height or depth
α, (ft² hr)	= average thermal diffusivity ($= k/\gamma c_p = 0.025$ for soil at Riverside, February, 1939)
ϵ, (non-dim)	= emissivity, whole-spectrum 32 F, grayness for half-space radiation
$c_g = \gamma\, c_p$, (B/ft³deg F)	= average volumetric heat capacity (= 29 for soil at Riverside, February, 1939)
λ_t, (B/lb deg F)	= latent heat of vaporization (= 1076 at 32 F) per F in reducing dewpoint
σ, $\frac{\text{B/hrft}^2}{\text{o}_\text{R}^4}$	= Stefan-Boltzmann constant for black-body radiation
θ, (hr)	= time

Effectiveness of Heaters for Frost Protection in Citrus Orchards

By Robert A. Kepner
MEMBER ASAE

DURING five winters of field tests at the University of California Citrus Experiment Station at Riverside, comprehensive studies of 9 different kinds of heaters were conducted in a one-acre heated portion of a larger citrus orchard. An extensive network of thermocouples was used to automatically record temperatures at various locations in both heated and unheated plots. Soil temperatures were measured to a depth of 12 in below the ground surface and air temperature to a height of 60 ft above the ground. On several occasions a captive balloon was used to obtain temperature and humidity-data up to heights of 300 ft or more. Other environmental factors, such as wind, atmospheric radiation, and heat flow from the soil were evaluated during the tests.

On five occasions during this period, isolated areas ranging in size from 7 to 28 acres were instrumented with portable equipment so that heating studies could be made on a larger scale.

Quantitative data were not obtained for so-called mass heating conditions, partly because there were very few nights during the 5-year period when extensive firing was required, and partly because of the difficulty of obtaining reliable unheated check temperatures when an entire district is heated.

In addition to the field studies, tests of individual heaters were conducted in the agricultural engineering laboratories at Davis to determine the radiant energy output and other thermal characteristics of several kinds of heaters at various burning rates.

ENVIRONMENTAL CONDITIONS INFLUENCING HEATING REQUIREMENTS

Since Brooks* discusses in detail the conditions under which frosts occur and the various heat-exchange processes involved, only brief mention of the most important environmental conditions will be included in this paper.

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

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AUTHOR'S NOTE: While no detailed heating studies have been made in deciduous orchards, the principles presented in this paper should be generally applicable. However, because the foliage is less dense in a deciduous orchard, the radiant energy from heaters probably is not used as effectively as in citrus orchards.

* Heat Transfers in Citrus Orchards Using Wind Machines for Frost Protection, by F. A. Brooks, C. F. Kelly, D. G. Rhoades, and H. B. Schultz. (See pages 74-78 of this issue).

Radiation Exchange. Most heating requirements are the result of nocturnal loss of heat by radiation to the cold sky. The air itself does not lose much heat by radiation, but becomes chilled mostly by contact with the cold ground or other exposed surfaces such as plant leaves, which are losing heat by radiation to the sky. The net rate of heat loss by nocturnal radiation is influenced by the moisture content of the atmosphere and its temperature, particularly in the lower thousand feet or so. On typical frost nights this loss is 20 to 25 Btu per hr per sq ft.

In an unheated area, the ground is the main source of the heat lost by radiation to the sky. Any practice, therefore, which increases the soil thermal conductivity will improve the availability of the soil heat and also increase the flow of heat into the soil during the daytime, thus reducing the frost hazard.

Air Temperature Inversion. The air cooled by contact with chilled surfaces is more dense than the warmer air overhead and therefore remains close to the ground, becoming colder as the surface temperature of the earth continues to fall. This is just the reverse of daytime conditions, when the ground and other exposed surfaces are heated by the sun and in turn heat the lower air and cause it to rise. Thus the vertical gradient of temperature during the night is an "inversion" of the daytime gradient.

In common orchard-heating terminology, a condition of large inversion is referred to as a low ceiling, because the heated air and products of combustion from the heaters rise only a relatively short distance before encountering natural air warm enough to restrict their rising. Conversely, with a small inversion or high ceiling, the overhead air for a given orchard temperature is not as warm as with a large inversion, and products of combustion will rise higher. This condition makes heating more difficult.

As indicated by the unheated temperature profile curves in Figs. 1 and 2, the increase of temperature with elevation is most rapid within the lower 50 to 75 ft. In all discussions following, the differences between the 60-ft temperatures and the 5-ft, tree-center temperatures in the unheated plot are arbitrarily taken as a measure of the magnitude of the inversion. (Figs. 1 and 2 are discussed in detail on page 82.)

Cold Air Drift. One of the major factors affecting the response from artificial heat, particularly in an isolated orchard, is air drift or cold air drainage. Even on nearly flat terrain, and with a relatively quiet night, the air drift across

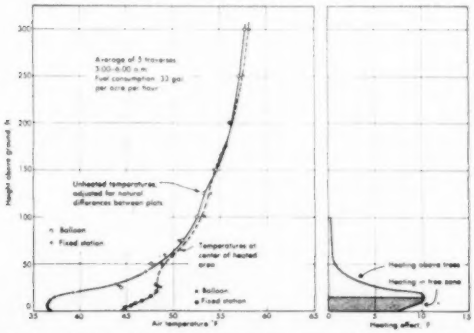

Fig. 1. Vertical profiles of temperature and heating effect in the center portion of 15-acre heated area, for a night with a large inversion.

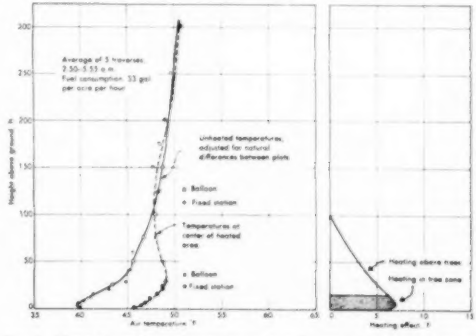

Fig. 2. Vertical profiles of temperature and heating effect in center portion of 15-acre heated area, for a night with a moderately small inversion.

an orchard may have a velocity of 1 to 2 mph at a 20-ft elevation. (Velocities within the tree zone will be perhaps one third as great as those at 20 ft.)

For several heating runs the amount of heat added to the incoming air was calculated by 5-ft air layers based upon the temperature increase and measured wind velocity for each layer. On two of these nights a 15-acre area was heated, with an average fuel input of about 84 gal per acre per hour and a wind velocity of 1½ to 2 mph at the 20-ft elevation. On a night when the temperature inversion was 7.5 F, 80 per cent of the total heat available from the oil being burned in the entire upwind half of the area was needed to heat the incoming air, 61 per cent of the total went into the air which entered the orchard above the 20-ft elevation and only 19 per cent was used to heat air entering below 20 ft. On the other night, the inversion was considerably larger (14 F) and less heat went into the overhead air. The totals that night were 39 per cent into the air above 20 ft, and 28 per cent into the air below 20 ft.

HEATER CHARACTERISTICS AND PLACEMENT IN THE ORCHARD

The utilization of the convective heat from orchard heaters is influenced somewhat by heater design, but the most important factor is the magnitude of the temperature inversion. When the inversion is small, most of the convective heat is wasted above the tree tops, and the radiant output from the heaters becomes most important. Radiant heating is especially important in border heating because, with proper placing of heaters, the radiant energy received by the trees and fruit can result in their temperature being several degrees above that of the surrounding air.

FIG. 5. Types of heaters tested. (*Upper left to right*) Hy-Lo 230A (12-cm stack), Riverside Junior Lowite (18-cm stack), Fugit (1937 models with generator parts shown, experimental coke). (*Lower left to right*) Jumbo Cone, "in Esdian's model, Kittle, experimental Return Stack.

Radiant Energy from Heaters. The radiant outputs at various burning rates for several kinds of heaters were determined in the agricultural engineering laboratories at Davis. Each heater was mounted on a pedestal about 10 ft above the floor, and radiation readings were made at 15-deg intervals of angle around the heater in a vertical plane. From these readings, the total radiant fraction (per cent of total fuel energy available as radiant energy) was calculated for each run.

Fig. 4 shows curves of total radiant fraction versus burning rate, for the six kinds of heaters shown in Fig. 5. With most of these heaters, the radiant fraction tends to remain about constant regardless of burning rate, especially at the higher rates. The experimental coke heater had the highest radiant fraction of the various kinds tested, while the Fugit was lowest. In general, the hot-stack or combustion-chamber types of heaters are better than other kinds of oil-burning heaters in regard to radiant energy output, because of the highest metal temperatures and the larger vertical-surface areas from which radiation takes place. Radiating surfaces need to be approximately vertical for maximum effectiveness in directing radiation to the trees rather than to the sky or ground.

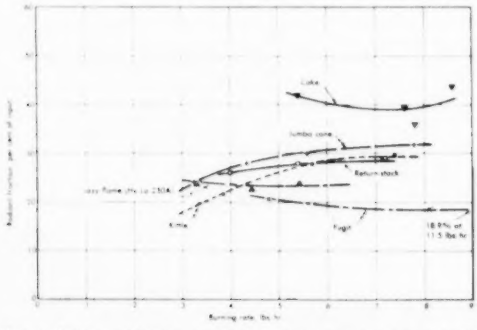

FIG. 4. Relation of total radiant fraction to burning rate for six kinds of heaters.

The portion of the heater's radiant energy intercepted by trees depends upon the tree size and spacing, and the location of the heaters with respect to the trees. Heat radiated to the ground is partially effective in the orchard since it results in some additional heating of the air in contact with the ground, but the energy radiated to the sky is practically wasted insofar as orchard heating is concerned.

Table 1 summarizes the radiant fractions from the various kinds of heaters and includes the results of calculations which show the distribution of radiant energy for two tree sizes. In general, with trees 12 ft in diameter and 12 ft high, the division of radiant energy between the ground, trees, and

Table 1.—Summary of Radiant Energy Outputs from Heaters

Kind of heater	Burning rate * (lbs hr	Radiant fractions, % of total fuel energy						Radiant fraction at lower burning rates
		Total from heater	12 x 12 trees			16 x 16 trees		
			to ground	to trees	to sky	to ground	to trees	to sky	
Heaters in centers of tree spaces, 20 x 24 tree spacing									
Exper. Coke	5.4	41.7	13.6	13.3	14.8	13.0	20.3	8.4	
Jumbo Cone	5.6	29.6	10.7	9.8	9.1	9.3	15.4	4.9	less
Return-Stack	5.4	27.6	9.8	8.9	8.9	8.7	14.1	4.8	slightly less
Kittle	5.7	27.5	12.0	8.6	6.9	10.6	13.8	3.1	less
Hy-Lo 230A	4.4	22.2	8.0	7.1	7.1	7.7	10.8	3.7	slightly more
Fugit	8.1	18.1	8.8	4.4	4.9	8.5	6.8	2.8	slightly more
Heaters in tree row, trees 20 apart, rows 24 apart.									
Jumbo Cone	5.6	29.6	10.1	13.4	6.1				less

* Calculations are for a particular test run at this burning rate. Radiant fractions remain about constant for burning rates above these values.

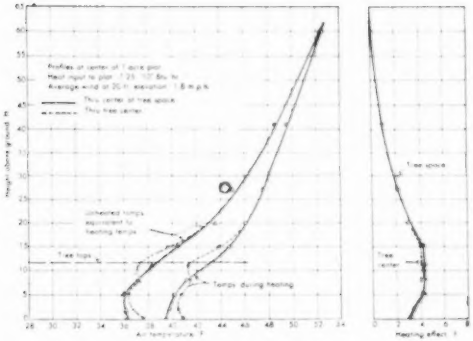

Fig. 5. Vertical profiles of temperature and heating effects at center of one-acre plot for a night with a large inversion. (Return-Stack heaters)

sky is about equal. However, the Fugit and Kittle heaters, because of their "hats", transmit nearly half of their radiant output to the ground.

Effect of Heater Placement. While the figures in Table 1 indicate the total amount of radiant energy received by the trees, they do not indicate the distribution between individual trees located at various distances from the heater. If one considers a single Jumbo Cone heater placed directly in the tree row between two trees (12 ft diameter by 12 ft high), 70 per cent of the total radiant energy received by all trees goes to the close sides of the two trees in the same row next to the heater. The nearest trees in the adjacent row on either side receive only 5 per cent each. If the same heater is placed at the center of the space (at intersection of diagonals) between four trees, each of these receives about 20 per cent of the total amount of radiat energy going to all trees. The next trees out receive only 1 to 4 per cent each.

Considering an orchard with heaters spaced one per two trees (every other tree in every row), the most uniform distribution of radiant energy is obtained when the heaters are at the centers of the tree spaces and all heaters are burning. Each tree then receives equal amounts of radiation from two opposite sides. By contrast, if only every fourth row of heaters is needed (one heater per 8 trees), the coldest rows receive very little radiant energy and hence must be heated almost entirely by convection.

HEATING TESTS IN THE ONE-ACRE PLOT

In order to obtain an accurate comparison of the effectiveness of various types of heaters based upon many tests under carefully selected operating conditions, a one-acre square plot within a larger orange orchard at the Citrus Experiment Station was instrumented, and groups of heaters were operated in it under various conditions. The trees were about 12 ft in diameter and 12 ft high and were planted on 20 x 24-ft centers. Heating runs were made on approximately 55 nights during three winters. These runs were all made on nights not quite cold enough to require protection, but under typical radiation frost conditions. Temperature inversions ranged from 4 to 20 F.

Arrangements and Kinds of Heaters. The different kinds of heaters tested are illustrated in Fig. 3. The Hy-Lo 230A and Riverside Junior Louvre heaters are of the lazy-flame type, in which most of the combustion takes place above the tops of the stacks. The Jumbo Cone, 7-in Exchange model, and Return-Stack heaters are classified as combustion-chamber or hot-stack heaters, since most of the combustion takes place in a combustion chamber at the base of the stack. The Kittle is also of the hot-stack type, but combustion is over a shallow trough rather than from the fuel storage bowl. The Fugit is a generator type which operates with fuel under pressure from a pipe line.

The experimental coke heaters were tested with radiation shields added, as well as without them, in order to compare the relative merits of convective heat and radiant heat under extreme conditions. Each shield consisted of two concentric cylinders of galvanized iron, 3 ft tall, open at both ends, and held above the ground about 4 in to allow the entrance of air. The clearance between the inner and outer cylinders was about 4 in, and the diameter of the inner cylinder was about 50 in. When the shields were used, the coke heaters became almost 100 per cent convective heaters, while with the shields removed these heaters had the highest radiant fraction of any heaters tested.

In general, heaters in the one-acre plot were placed in the centers of the tree spaces, with one heater per two trees within the plot. Border heaters were spaced one per tree on all four sides, giving a total of about 70 heaters for the entire heated plot. A few tests were made with Fugit heaters spaced one per three trees within the plot, but still with one per tree on the upwind borders.

Test Setup and Procedure. Temperatures from thermocouples at many locations in the heated plot and in a similar upwind, unheated area, were recorded automatically at 10-min intervals. The usual heating period during a run was about 5 hr. Temperatures were generally recorded for a 2-hr period just before the heaters were lighted in order to establish natural differences between temperatures in the two plots.

For determining the responses or heating effects from different kinds of heaters, the 5-ft air temperatures at the centers of four adjacent trees in the middle of the heated plot were averaged and compared with corresponding temperatures in the unheated check plot. In addition, vertical profiles of temperatures taken near the center of the heated plot were compared with similar temperatures in the unheated plot.

During some of the runs, leaf and fruit temperatures were measured in addition to air temperatures. While these temperatures are the critical ones to consider in determining the amount of protection required during dangerous periods, they may vary several degrees for different exposures and locations on the tree. For example, fruit exposed directly to heater radiation will be warmer than the air, while fruit on the "dark" side of a tree and exposed to the sky will be colder than the air. Since heat transfer to or from the air tends to average out variations between individual fruits and leaves, air temperatures were used for all heater comparisons.

The total amount of fuel consumed during each run was determined by weighing the heaters individually before and after the run, using a specially designed portable scale unit. Only one kind of heater was tested in the main plot during any particular night. However, occasional runs with the Hy-Lo 230A heaters were made during each of the several winters of the study, as a check against possible changes in results from season to season. The results obtained with this kind of heater were remarkably consistent from year to year.

Vertical Profiles of Temperatures. Fig. 5 shows air temperatures and the response from heaters in relation to height above ground, for a typical run with large inversion. Note that the maximum response of about 4 F in the one-acre plot was between heights of 5 and 15 ft, and there was no measurable heating effect above 60 ft. The dotted temperature curves at the left indicate that the air in the treetops was colder than air at the same height between trees, in both the heated and unheated plots. This is due to the loss of heat by radiation to the sky from the relatively large treetop area. Near the ground the situation is reversed because the soil beneath the trees is protected from sky radiation.

The unheated curves in Figs. 1, 2, and 5 all indicate that the coldest air in the orchard is from 2 to 5 ft above the ground, rather than at the ground surface. In an orchard, the exposed foliage, because of its low heat capacity, cools rapidly to an equilibrium temperature enough colder than the surrounding air so that convective transfer from the air to the foliage balances the net radiation loss. The equilibrium temperature of the soil surface is higher than that of the foliage because of the high heat capacity of the soil and the resulting flow of heat to the surface; this accounts for the

air at the ground surface being warmer than that a few feet above the ground.

Relative Effectiveness of Different Heaters. For direct comparison of the results from various kinds of heaters, the average 5-ft, tree-center heating effects for the individual test runs were adjusted by proportion so that they would all represent the same fuel input to the plot (50 gal of oil per hr, or an equivalent amount of coke).

Fig. 6 shows curves of heating effect in relation to temperature inversion for the different kinds of heaters tested. The experimental points representing individual runs have been omitted from the graph. Each curve, however, is based upon at least 3 runs at different inversions. The results from 11 of the 55 nights were not used because of periods with wind or unsteady conditions during the tests. Of the 44 runs used in plotting these curves, only 4 were more than 10 per cent above or below the curves as drawn.

The curves of Fig. 6 confirm field experience that, regardless of the kind of heater, the response for a given fuel input is less for small inversions than for larger ones. When the inversion is large, there appears to be little choice as to type of heater, but at the small inversions there are definite differences in effectiveness. At 6 F inversion, for example, the response with Fugit heaters spaced one per 3 trees was only half as great as with coke heaters for the same heat input in the plot.

Of the bowl-type heaters tested, the lazy-flame heaters were the least effective at small inversions, while the Jumbo Cone and 7-in Exchange heaters appeared to be the best. If values of heating effect are taken from Fig. 6 for the various heaters at a small inversion (5 F), it can be shown that the effectiveness or response of the various heaters at this inversion in the one-acre plot was in almost direct proportion to the radiant fractions to 4trees plus ground. Within the center portion of a large heated area there might not be so much difference between kinds of heaters, but they should still rank in the same order of effectiveness.

Taking the extreme comparison of coke heaters with and without radiation shields, Fig. 6 indicates that, even at an inversion as large as 10 F, the shielded heaters (with practically no radiant energy output) gave less than 40 per cent as great a response as did the same heaters with shields removed (high radiant output). However, when the inversion was 1° F, the response with the shielded heaters was 65 per cent as great as that with the unshielded. It is probable that at an extreme inversion of 22 to 25 F, there would be little difference in the heating response with or without shields.

In other words, when the inversion is small, most of the convective heat (hot stack gases and heated air) rises above the tree tops and is lost. Under these conditions, radiant heating must be the principal means of protection. With a large inversion more of the hot gases are held down within the tree zone to supplement the effect of radiant heat. Therefore, the smaller the inversion, the more advantage there is in using heaters with high radiant fractions.

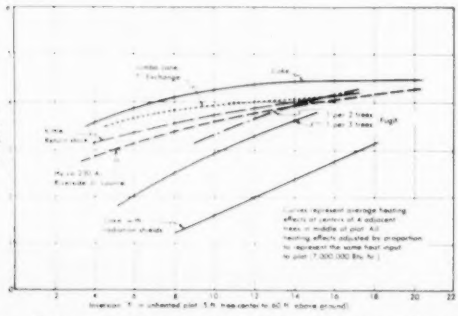
Jumbo cone
7" Exchange
Coke
Fugit
1 per 2 trees
1 per 3 trees
Curves represent average heating effects at centers of 4 adjacent trees in middle of plot. All heating effects adjusted by proportion to represent the same heat input to plot (7,500,000 Btu hr.)
Inversion, °F. in unheated plot, 5 ft. tree center to 60 ft. above ground)

Fig. 6. Effect of temperature inversion and kind of heater used upon heating response measured at center of one-acre plot.

HEATING OF ISOLATED ORCHARDS

Five test runs were made with heated areas ranging in size from 7 to 28 acres. All of these tests were in orange orchards with trees about 15 ft in diameter and 15 ft high, planted on either 22x22 or 20x24-ft centers. In each case, the heaters were placed in the tree rows with one heater per two trees within the orchard. In some cases, however, only part of the heaters were lighted.

Fifteen-Acre Area at Riverside. During two nights when minimum temperatures were about 35 F (not quite cold enough to actually require protection), a 15-acre square plot was heated, using all of the 45 heaters per acre within the area. During the last half of the 4-hr heating period on each night, the upwind border was increased from one heater per 2 trees to one heater per tree. On the other 3 sides, the regular spacing of one per 2 trees was maintained. Most of the heaters were equipped with 7-in Exchange stacks, and the average burning rate on each night was ¾ gph per heater.

Thermocouples were placed at the centers of various trees along the middle row across the plot, to obtain heating effects at various distances in from the edge of the heated area. The permanently instrumented plot used for one-acre studies served as the unheated check station for these tests. In addition to the tree-center temperatures, vertical temperature profiles were measured in the unheated plot and at the center of the heated area. Two captive ballons, operated simultaneously at these two locations, were used to obtain temperatures above the height of the thermocouples mounted on poles.

Figs. 1 and 2 show vertical temperature profiles up to 300 ft for the two nights. The difference between the heated and unheated curves is shown at the right on each graph and represents the heating response. For the night with 14 F inversion (Fig. 1), the graph indicates practically no heating effect above 50 ft; while on the night with only 7.5 F inversion (Fig. 2), there was a definite response up to 100 ft but none above that elevation. When the inversion is small, there is less heating effect within the tree zone than with larger inversions, but heating extends to a higher elevation as shown by these graphs because the hot stack gases and warmed air rise more readily and must go higher before their temperature reaches the same value as that of the surrounding air.

Fig. 7 shows the variation of 5-ft, tree-center heating effects across the heated area. The 20-ft air drift during these tests was 1½ to 2 mph and was consistently from east to west (from left to right on the graphs). The top graph contains two curves—one for the night with 7.5 inversion and one for 14 F. The tree-center responses throughout the heated area were 15 to 20 per cent less on the night with the smaller inversion. In both cases, the heating effects obtained in the center portion of the area were about as large as can normally be obtained in general heating practice.

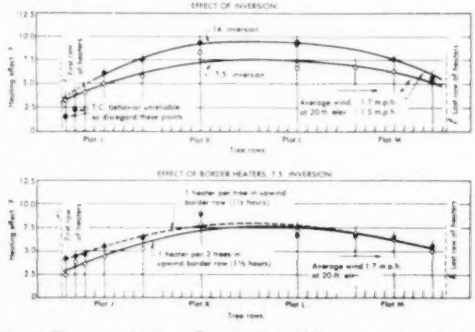
EFFECT OF INVERSION
14° inversion
7.5° inversion
Average wind 1.7 m.p.h. at 20-ft elev. 1.5 m.p.h.
Tree rows
EFFECT OF BORDER HEATERS, 7.5° INVERSION
1 heater per tree in upwind border row (1½ hours)
1 heater per 2 trees in upwind border row (1½ hours)
Average wind 1.7 m.p.h. at 20-ft elev.
Tree rows

Fig. 7. Tree-center heating effects in the middle row across a 15-acre heated area. Average burning rate was 0.75 gph per heater, using 45 heaters per acre. These results do not include the lighting period.

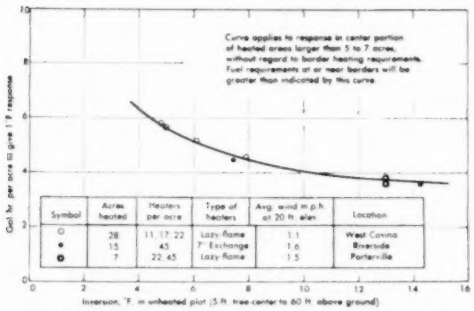
Curve applies to response in center portion of heated areas larger than 5 to 7 acres, without regard to border heating requirements. Fuel requirements at or near borders will be greater than indicated by this curve.
Gal. hr. per acre to give 1° response
Inversion, °F. in unheated plot (5 ft. tree-center to 60 ft. above ground)
Symbol | Acres heated | Heaters per acre | Type of heaters | Avg. wind m.p.h. at 20 ft. elev. | Location
○ | 28 | 11, 17, 22 | Lazy-flame | 1.1 | West Covina
● | 15 | 45 | 7° Exchange | 1.6 | Riverside
◐ | 7 | 22, 45 | Lazy-flame | 1.5 | Porterville

Fig. 8. Effect of temperature inversion on fuel requirements per degree of response in the center portion of 7- to 28-acre heated areas.

During each of the two runs, the heating effect at the upwind edge was only about 40 per cent as great as in the center portion, gradually increasing toward the center of the plot and then decreasing again beyond the center, although on the *downwind* side. Obviously the increase in heating effect from the upwind edge toward the center is due at least in part to the progressive warming as the natural air drift carries the incoming air past more and more heaters.

It might be expected that the heating effect would continue to increase in this manner nearly to the downwind edge of the plot, but, as indicated in Fig. 7, this was not the case. The response gradually decreased in the last 10 or 12 rows and at the downwind edge was only 60 per cent as great as in the center portion. When a sensitive wind vane was placed at the downwind edge about 3 ft above the ground, it indicated a definite movement of air into the orchard at this height, *directly against the prevailing air drift.*

Some indication of the vertical depth of this indraft may be obtained from results for a few one-acre runs when vertical temperature profiles were measured in the second tree row from the downwind edge, as well as at the center of the plot. Composite results for 6 nights whose average inversion was 6 F show that, throughout the lower 20 ft of elevation, the heating effect at the downwind edge was about 15 per cent less than at the center of the plot; while above 25 ft there was no difference between the two locations. Six other nights with an average inversion of 14 F had 25 per cent less heating effect near the downwind edge in the lower 15 ft and showed no difference above 20 ft.

Thus for an isolated orchard, the rising stack gases and heated air apparently create an updraft which draws in cold air from all sides of the plot, at least if the prevailing natural drift is small. Reduced reradiation from the overhead heated gases and from the trees near the edges of the heated area may also contribute to the lesser response. Regardless of the cause of the reduced heating effect, it is evident that extra border heaters are needed on all sides of an isolated orchard, although in greatest numbers on the upwind side.

The bottom graph in Fig. 7 indicates that when the number of heaters on the upwind border was doubled (to one heater per tree), the response increased by about 50 per cent at the edge, and by lesser amounts throughout the upwind 10 or 12 rows. No tests were run with heavier border concentrations or with extra heaters on the downwind or side borders.

Seven-Acre Heated Area. On a night when intensive general heating was necessary in the Tulare citrus district (central California), portable test equipment was set up and operated in a 7-acre heated tract which was part of a larger unheated orchard. Temperatures were measured only at the center of the heated area and in the upwind unheated area. A captive balloon was operated at the heated station.

Within the plot, lazy-flame heaters were spaced one per two trees (45 heaters per acre), while on all four sides of the heated area the spacing of border heaters was one per tree. Starting at 11:30 p.m., all of the border heaters and every other row of the heaters within the plot were lighted. At about 3:30 a.m. the remainder of the heaters were lighted, and heating continued until about 7:30 a.m. During the first heating period, the average response was 4.1 F, while with all heaters burning, it was 8.8 F. The average burning rate was 0.7 gph and the temperature inversion was 13 F.

The average vertical temperature profiles obtained between 3:00 and 6:00 a.m. were similar in shape to the ones for the Riverside run with similar inversion (Fig. 1), but with temperatures 12 to 14 F colder at all heights up to the 300-ft limit of the reading. There was no indicated heating effect above 100 ft and very little above 50 ft.

Twenty-Eight-Acre Heated Area. Two runs were made in an isolated orange orchard near West Covina (Los Angeles County) on nights when light or moderate general firing was required. The terrain at this location is very flat, since the orchard is located on the floor of a valley. Even so, the average 20-ft wind velocity during the two nights was 1 to 1½ mph. On one of the two nights, this orchard was heated from 1:30 to 8:00 a.m., using only every fourth row of heaters (11 per acre). During the second night the same heaters were lighted at about 1:00 a.m., but additional heaters were lighted at 4:00 a.m. and at 6:30 a.m., to give a total of 22 heaters per acre. Lazy-flame heaters were used, with an average burning rate of 0.5 gph during each night.

The average inversion was 8 F on the first night and 5.5 F on the second. Vertical temperature profiles (not shown) indicated no response above 100 ft on either night. The average tree-center heating effects in the center portion of the orchard were a little more than 1 F when one-fourth of the heaters were in use, and about 1.9 F when half of the heaters were burning. Tree-center temperatures during both of the nights indicated that, when only every fourth row of heaters was burning, trees in the three cold rows each had about 25 per cent less response (0.3 F less) than trees in a row containing lighted heaters.

When only every fourth row of heaters was burning, the response near the edge of the orchard was nearly as great as in the center. As the number of heaters was increased, the difference between the center response and that near the edge increased, perhaps because of additional indraft caused by the stronger orchard stack action with more heaters.

Relation of Response to Size of Heated Area. The effect of temperature inversion upon fuel requirements per degree of response at the centers of the 7-acre, 15-acre, and 28-acre orchards is shown in Fig. 8. The fuel inputs in gallons per hour per acre were based upon the average heater spacing withing the plot, without regard to border heaters. Where the number of heaters used per acre was changed during a particular run, separate points were plotted for each period.

Although the actual fuel inputs for different runs varied from 6 to 34 gph per acre, and the plots were in three different localities with sizes ranging from 7 to 28 acres, the results fit a single curve rather closely. This indicates that in the center portion of a heated area, beyond the influence of border conditions, the response is relatively independent of the size of the area heated. The curve indicates a considerable increase in fuel requirements as the inversion decreases below 12 to 14 F. For example, the fuel requirements at an inversion of 4 F would be 50 per cent greater than at 10 F.

In tests with the 15-acre plot (Fig. 7) the reduced response due to border effects extended in 10 to 15 rows from the edge. The response was practically constant throughout the center portion of the orchard and was about as large as is normally expected even in mass heating. Thus, although the largest heated area involved in these tests was 28 acres, it is probable that the fuel requirements indicated by Fig. 8 would apply to larger areas on reasonably flat terrain. This curve should not, however, be used for areas of less than 6 to 8 acres, because the reduced response due to border effects is likely to extend in to the center of areas smaller than this limit.

Regardless of the size of heated area, the fuel requirements

near the edges will be greater than those indicated in Fig. 8 for the center portion. Conversely, if heaters are uniformly spaced, with no extras on the borders, the response near the edges of the orchard will be less than in the center. The magnitude of this reduction of border response is influenced considerably by the total rate of fuel consumption per acre per hour. For example, in three runs with heater spacings of 11, 22, and 45 per acre, in 15-acre or 28-acre orchards, the following results were obtained:

Total fuel rate, gal per acre per hr	Response at third tree in from upwind side
5.5	50 per cent as great as in center of area
11.0	70 per cent as great as in center of area
22.0	90 per cent as great as in center of area

The greater reduction in border response with the higher fuel inputs indicates a more rapid inflow of cold air caused by increased updraft over the orchard.

Results obtained from comparable tests with the different sizes of heated areas indicate that the response at a given distance in from the upwind edge (but not beyond the center) is about the same regardless of the size of the plot. For example, with 7-in Exchange heaters and similar conditions, the tree-center heating effect at the fifth row in from the upwind side of the one-acre plot (at center of plot) was almost as great as in the 15-acre plot at the same distance in. Likewise, the response obtained near the center of the 7-acre orchard (12 rows in) agrees quite well with results obtained in the 15-acre plot.

Since the response appears to be a function of the distance in from the edge, the extensive results obtained in the one-acre plot regarding responses and relative effectiveness of different kinds of heaters should be directly applicable to a strip around the outside of a larger isolated orchard. The importance of border considerations becomes more apparent when one considers that, with 90 trees per acre, a strip only 5 trees wide all around a 15-acre area, or 7 trees wide around 30 acres, represents half of the orchard.

Border Heaters for Isolated Orchards. While the tests did not include enough large-plot runs to actually check the best arrangement of border heaters for a uniform response, sufficient information is available to serve as a basis for recommendations in this respect[5]. The following general considerations should be kept in mind in regard to border heaters:

(a) High radiant output from the heaters is especially important in border areas, so that the outside trees may be heated directly, without the necessity for warming all of the inflowing air before it gets into the orchard. If a grower has more than one kind of heater, those with highest radiant fractions should be used on the borders.

(b) Border heaters should be distributed over the first two or three rows in, rather than all concentrated on the outside. This will allow a greater percentage of the tree surfaces in the outer rows to be "seen" by the heaters and thus be heated directly by radiation.

(c) Avoid excessive burning rates for border heaters, use larger numbers of properly distributed heaters at normal burning rates. In the center portion of the orchard, burning rates should be kept as low as possible to minimize updraft which draws in cold air along the borders.

(d) Border heaters are usually needed on all sides of an isolated heated area but with greatest numbers on the upwind side. Never use less than one heater per two trees on any outside edge.

LARGE-SCALE HEATING

In the so-called mass heating of large areas, the fuel requirements within the heated district will probably be a little lower than indicated by Fig. 8. Within a large heated area (beyond border influences), fuel requirements are determined primarily by the heat input required to counteract the normal radiation losses plus the additional losses resulting from the higher temperatures of the trees, air, and soil surface in the heated orchard.

For large-scale heating, the border effects are confined mainly to the orchards on the outer fringes of the heated district. However, if an orchard well within a heated district does not have other heated areas reasonably close, it will probably need some extra border heaters.

As with borders and isolated orchards, the use of heaters with high radiant energy outputs will give somewhat better response for mass heating, particularly when the inversion is small and heating requirements are severe.

SUMMARY

The principal factors which affect the amount of fuel required for a given temperature response in an orchard are:

1 Magnitude of temperature inversion. Heating is most difficult on nights with small inversions or so-called high ceiling.

2 Inflow of cold air, due either to natural drift or to the combined stack action created by the heaters in an isolated orchard. In the heating of large areas, the effect of inflow diminishes, except for border orchards.

3 Heater characteristics, particularly in regard to radiant energy. With a small inversion the convective heat is largely wasted above the tree tops, and radiant heat thus becomes the principal means of protection.

The total radiant fractions (per cent of total fuel energy available as radiant energy) for the various types of heaters tested were as follows: coke, 40 per cent; hot-stack type, 27-30 per cent; lazy-flame type, 22 per cent; generator type, 18 per cent. Except for the Kittle and generator heaters, which transmit nearly half of their radiant energy to the ground, the division of radiant output in a citrus orchard with 12x12-ft trees is about equal between ground, trees, and sky.

In the one-acre heating studies, there was little difference between the various kinds of heaters in regard to effectiveness when the inversion was large. When the inversion was small, however, the effectiveness was directly related to the radiant fractions of the heaters.

Five test runs were made in isolated orchards ranging in size from 7 to 28 acres with inversions of from 5 to 14 F (difference between 5-ft and 60-ft temperatures), and with fuel inputs from 6 to 34 gal per acre per hour. Fuel requirements for a given tree-center response within the center portions of the areas were consistent for all of these tests and indicate a definite increase as the inversion becomes smaller. In none of the tests was there any measurable response at heights greater than 100 ft above the ground. With fairly large inversions, the heating effect was confined mostly to the lower 50 ft, while with small inversions there was considerable heating between 50 and 100 ft (practically useless to the orchardist).

A definite orchard stack action, created by the rising of the heated air and gases from all the heaters, was observed and is indicated by the test results. Cold air apparently is drawn in from all sides of an isolated heated area, with the depth of inflow probably being as great as the tree height, even on the downwind side.

The combined effect of the natural air drift and the inflow of cold air caused by this orchard stack action is to reduce the response for as much as 10 to 15 rows in from the edges. The degree of reduction of border response is greatest for high rates of fuel input per acre, because of the increased orchard stack action and indraft. Thus it is important to operate the heaters, especially those within the plot, at the lowest rates which will give adequate protection.

Border heaters should be distributed over the first two or three rows in, rather than all concentrated on the outside of the orchard. Heaters with high radiant output are especially advantageous in border heating. Border heaters are needed on all sides of an isolated orchard but with greatest numbers on the upwind side.

[5] Detailed recommendations for border heating are included in University of California Bulletin 729, Effectiveness of Orchard Heaters, by Robert A. Kepner, May, 1951.

A Dew-Point Moisture Indicator

By Norton C. Ives
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IN WARM, humid climates molds and insects cause deterioration and loss of vast quantities of grains, beans and other dried feedstuffs. It has been shown that mold development is not only closely associated with, but is the apparent cause for most of the initial, rapid deterioration in damp grains, beans or other dried feedstuffs (2, 9, 10, 11, 12, 13)*. Furthermore, it has been shown that the ability of mold to develop on dried cereals and legumes at normal temperatures (20 to 30 C.) is very closely associated with or dependent upon the relative humidity of the interstitial air. If the relative humidity of the interstitial air of such materials is a key factor that determines the ability of molds to develop on these materials, then it should serve well as a measure of the condition of the material for storage. For the grains and beans which have been studied, it has been reported that a relative humidity above 75 per cent will result in mold development in a matter of days. At 70 per cent relative humidity, a much longer time is necessary, and for storage periods of more than a year a relative humidity below 65 per cent is necessary to control all the important damage-producing molds (12). A relative humidity condition in the region of 55 per cent or below will practically prevent development of most insects found in storage (5, 8).

There is very good evidence on the basis of these studies that a common measure of the condition of any dried feedstuff for storage is the value of the relative humidity of the interstitial air in equilibrium with the moisture still remaining in the dried material.

The relationships between the moisture content and the relative humidity of the surrounding air under equilibrium conditions have been measured for most commercially important hygroscopic materials (1, 7, 14, 15). Fig 1 shows such an equilibrium moisture curve for shelled corn at 25 C. Variation of the grain temperature over the normal range of room temperatures has little effect on the corresponding values of the grain moisture and air relative humidity.

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*Numbers in parentheses refer to the appended references.

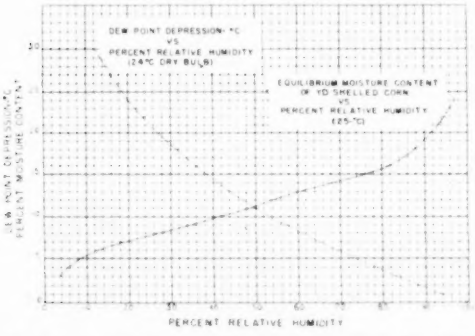

Fig 1. Curves showing (a) equilibrium moisture content for shelled corn at 25 C. and (b) dew-point depression for a dry-bulb temperature of 24 C.

Also plotted in Fig. 1 is a curve showing dew point depression for a dry-bulb temperature of 24 C, versus relative humidity, which relationships are not affected by changes in the barometric or air pressure. Also it so happens that over a normal range of room temperatures, any variation in the dry-bulb temperature has little effect on the corresponding values of the dew-point depression and relative humidity. So for practical purposes, normal variations of room temperatures above or below 25 C may be ignored with little error.

It is apparent then that nature presents a set of convenient relationships which make it possible to measure the moisture condition of a grain-air mixture or other material by taking measurements with an ordinary thermometer.

This paper describes an apparatus low in cost and easy and simple to operate for measuring the dew-point and dry-bulb temperature of an enclosed grain-air mixture, and thereby the relative humidity of the interstitial or ambient air of the grain. It is suitable for a large variety of materials—grains, beans, hays, feeds, fibers, wood, etc.—in the hygroscopic moisture range, but its use will be described for whole kernel grains or beans in the discussion which follows. Dexter (4, 5, 6) and other workers have reported on various other techniques employing certain of these basic relationships to determine grain and other material moisture conditions.

The apparatus is essentially a dew-point hygrometer adapted for operation in a closed container. The essential parts of the tester are listed and shown in Fig. 2.

OPERATION

The procedure to be followed depends somewhat upon the accuracy desired. The following procedures, with representative results shown in Table 1 and discussed under "Accuracy," have been used with a handmade dew-point hygrometer unit and a two-quart, wide-mouth glass fruit jar.

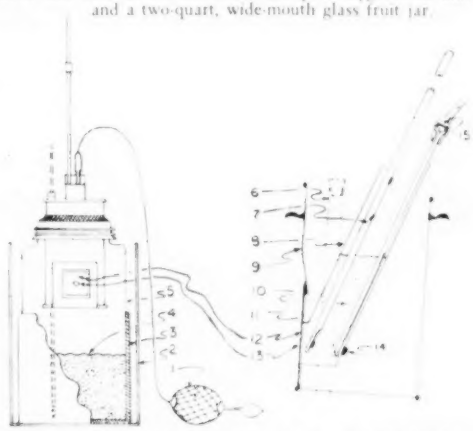

Fig 2. Essential parts of dew point tester. (1) syringe and bladder from an aspirating psychrometer, (2) outer container for insulation purposes only (desirable when a series of readings are to be made), (3) insulating sock (desirable when single-wall glass jar is used), (4) approximate level of sample in jar, (5) two-quart, wide-mouth glass fruit jar, (6) copper-tube thermometer well for taking grain temperature, (7) glass-stem, indexed thermometer, (8) refrigerant container, (9) outer metal-wall container of dew-point hygrometer unit, (10) refrigerant (acetone), (11) non-hygroscopic, water vapor impermeable, heat insulating bond, (12) chromium plated, condensing surface (well cleaned and polished), (13) diamond-shaped, treated area (invisible before condensation), (14) metal tube yoke for mechanically fastening refrigerant container to outer container, (15) aspirating air-metering orifice (20-gauge hypodermic needle for acetone).

TABLE 1. EQUILIBRIUM MOISTURE CONTENTS FOR SOME COMMON GRAINS AT CRITICAL DEW POINT DEPRESSION VALUES (Data from references 7 and 15)

Dew point depression	5 C	7 C	8 C	10 C
Corresponding relative humidity	73.8%	65.1%	61.1%	36.2%
Shelled corn YD	14.7	13.6	13.1	9.2
Wheat HRW	14.4	13.2	12.8	9.3
Wheat HRS	14.0	12.8	12.3	8.1
Rice, rough	13.9	12.9	12.8	8.9
Rice, milled	14.2	13.2	12.9	9.9
Rice, polished	15.3	14.0	13.7	10.6
Soybeans	12.8	10.3	9.9	7.0
Oats	14.6	12.4	12.1	8.8
Barley	14.1	12.9	12.4	9.1
Sorghum	13.9	13.1	12.8	9.3
Flaxseed	9.9	8.6	8.1	6.0
Rye	14.6	13.1	12.7	9.5

Several possibilities for greater accuracy or better control will present themselves to the reader as the operation of this simple unit is described. But one of the basic objectives in the development of this unit was to keep it as simple and versatile as possible. Studies then were made to determine the probable accuracy of this model according to certain procedures and probable usage.

To make a test, the grain-air mixture is allowed to come to equilibrium in the closed jar with dew-point apparatus inserted. The grain temperature is determined; then dew-point temperature is determined by aspirating air through the liquid refrigerant in which thermometer is placed, until condensation occurs on the polished chromium surface, seen through the glass wall of the container. The difference between these two readings is the "dew-point depression" or "degrees depression".

INTERPRETATION

The relationships between moisture content and relative humidity for shelled corn, and relative humidity and dew-point depression for an air and water-vapor mixture are shown in Fig. 1. As already mentioned, these relationships are such that the dew-point depression itself may be used directly as a measure of the grain condition. Thus 5 C depression shows the grain-air moisture condition at the critical point for short-time handling or storage; a dew-point depression of 7 C. shows the grain to be safe, but with little margin of safety for relatively long-time storage. As 8 C. depression may be considered optimum for long-time storage. Grains dried to 16 C. dew-point depression will have good resistance to weevil infestations so prevalent in warm, humid climates. Such dry grain will also possess a large margin of safety against mold development due to moisture regain in humid regions. Table 1 gives the moisture contents which correspond to these dew-point depression values for some of the common grains.

ACCURACY

Theoretically it appears that such an instrument may have capabilities of very high accuracy. In its present form, however, it is subject to different sources of errors, the most important of which appear to be the following, listed in their usual order of importance.

1. *Disequilibrium Conditions Between the Air and the Grain Moisture.* When quick tests are made, this is the greatest of any error. To estimate the probable magnitude of this error, the dew-point temperature of the atmospheric air should be determined. Any error will tend to vary directly as the magnitude of the difference between the degrees atmospheric depression and the degrees grain-air depression, and in the direction toward the atmospheric air reading. Thus, if a quick check is to be made of relatively damp grain in lower relative humidity atmospheric air, for example, and if the reading is less than the critical or desired value, it is sure that the grain is too damp; that is, any error would indicate the grain to be drier than it actually is.

Continuous mixing of the grain and air for a few minutes will greatly decrease the time necessary to bring this error to a desired minimum. Table 2 gives data illustrative of the effects of mixing. Mixing, however, is not necessary if the grain samples are left for several hours — overnight, for example — in tightly closed containers and then the dew-point apparatus inserted quickly a few minutes before the measurement is made.

2. *Temperatures and Temperature Gradients.* Uniform

TABLE 2. TYPICAL PERFORMANCE DATA OF EXPERIMENTAL DEW POINT TESTER

Time	Grain temperature, C	Dew point temperature C	Degrees depression	Operation
0 min	——	——	——	—Well-cleaned sample and shelled corn poured several times through 5 C. dew point depression air. Tester unit inserted immediately. No mixing of corn with air in jar at any time.
2 min	26.0			
4 min		17.8	8.1	
11 min	26.0			
15 min		16.9	9.0	
8 min	26.0			
86 min		16.0	10.0	
2 hr	26.0	16.0	10.0	
9 hr	26.0	15.9	10.1	—Corn wet, poured through 5 C. depression air, then in jar closed with jar lid.
0 min	——	——	——	—Jar rolled slowly for two minutes.
2 min	——	——	——	—Tester unit inserted.
6 min	26.0			
8 min		15.9	10.1	—Refrigerant removed from tester, then jar rolled one minute.
10 min	26.0			
38 min		16.1	9.9	—Jar rolled again for two minutes.
50 min	26.0			
51 min		15.9	10.1	—Corn wet again, poured through air, then back into jar.
0 min	——	——	——	—Closed with jar lid.
13 hr	——	——	——	—Tester inserted.
7 min		14.8	11.2	—After first reading, jar rolled for 15 sec.
4 min		15.9	10.1	
10 min	24.8			
29 min	24.8			
1 hr 27 min		14.8	10.1	
1 hr	24.8	14.8	10.1	
1 hr 15 min	24.8	14.8	10.1	
1 hr 30 min	24.8	14.8	10.2	—A series of 15 consecutive readings gave 2—10.1 deg.; 9—10.2 deg.; and 2—10.3 deg. Temperature of corn at end of readings was 24.9 deg.
30 min	——	——	——	—Dusty sample of rough rice from over a $Ca(NO_3)_2$ constant humidity salt solution (51% at 24.5 C.). Sample shaken 30 times in jar, then tester inserted.
2 hr	26.0	15.2	10.8	
5 hr	26.0	15.0	11.0	
13 hr	26.0	14.9	11.1	
35 hr	25.9	14.9	11.0	—11.0 − 0.4 = 10.6 C. true depression which is a relative humidity very close to 51%.

temperatures of grain and container, mixing the grain, and protecting the container from exterior temperature variations such as caused by the hands or breath, will prevent undue temperature gradients from developing in the grain, when several consecutive readings are to be made and high accuracy is desired. As shown in Table 2, several consecutive readings have been made with this apparatus with grain temperature changes of only a few tenths of a degree.

Special care is necessary to measure grain temperatures accurately with an ordinary glass thermometer. The thermometer should be brought to the estimated temperature of the grain before insertion into the grain, and the grain should be well mixed before the final temperature is read. When reading to the nearest 1/10 deg, readings one minute apart that do not change, with the grain mixed after every reading, may be safely assumed to give the true temperature of the grain to within plus or minus 1/10-deg accuracy. Accurate dew-point temperatures, aside from the original design of the instrument, depend upon good control of the aspirating air and quick detection of initial condensation. The first is controlled by the degree of bladder inflation and/or by partially pinching the rubber tube. Much time generally can be saved by cooling rapidly the first time down and noting the temperature after formation of an easily detected film of condensation. Replacing the cold refrigerant with warm refrigerant makes possible any desired number of redeterminations. For damp grains warm water may be used to advantage for flushing to warm the unit 5 C or more above the dew-point temperature.

For accurate readings the polished chromium condensing surface must be free of any hygroscopic material; in fact, any portion of the apparatus exposed to the enclosed air must be non-hygroscopic. A thin film of wax from a polishing cloth, while completely invisible at temperatures considerably above the dew point, will usually whiten at temperatures near to but slightly above the dew point. This makes accurate reading very difficult. Soft paper tissue or frayed linen can be used for polishing; cotton often leaves an undesirable film. Various surface treatments have been tried to provide quickly visible contrast at initial condensation. The best discovered so far is a geometrical design, such as a diamond-shaped figure about four millimeters across, placed on the acetone-cleaned, condensing surface by cutting the diamond out of a piece of cellulose tape used as a mask, and then applying a layer of Duco household cement on the exposed diamond-shaped surface, letting it thoroughly dry before removing and polishing. This diamond-shaped area, if kept properly cleaned, will "whiten" at or very near to the initial point of condensation in contrast to the surrounding area. This makes for quick, easy detection. If dimmed by polishing with acetone, it can be renewed easily.

The temperature gradient between the thermometer and condensing surface for the experimental model (chromium plated, 22-gauge steel), as measured with fine wire thermocouples, was approximately 0.2, 0.4, and 0.6 C for 5, 10, and 15 C dew-point depressions, respectively. Checking the entire apparatus with a constant-humidity sodium chloride solution at 24 C, the depression reading varied between 4.8 and 4.9 C by the thermometer. This indicated substantially the same error due to temperature gradient as the fine wire thermocouple. Thus for this instrument the corrected reading for a 10-deg measured depression would be 9.6 C.

3 *Moisture Gradients.* With thorough mixing of the grain, this type of instrument will tend to measure the mean value of moisture in the grain-air mixture. The actual transfer of moisture between the grain and air to obtain equilibrium conditions is indeed small, while the amount taken from the air to form a detectable condensate film is much smaller. For example, the ratio of water in dry grain to that in the interstitial air (around 0.4 by volume of the space) is in the order of 17,000 to 1, while the subtraction of moisture from the air in a two-quart tester to form a detectable film of condensation on the apparatus would lower the dew-point temperature in the order 1/100 C, if no replenishment from the grain occurred.

CALIBRATION

As pointed out in the previous discussion, this type of tester does not require calibration for the various grains, unless some idea is desired as to the actual water content of the material. This information as shown for corn in Fig 1 is available for most of the common grains as given in part in Table 1. An absolute calibration of the instrument may be accomplished by use of constant humidity salt solutions. Care should be exercised here to prevent any part of the solution forming on a surface above the liquid level. If allowed on the cooled surfaces of the hygrometer, it may introduce error due to changed vapor pressure of part of the liquid within the container.

SUMMARY

1 Various investigations have indicated that molds are the causative agent for most damp grain, bean and other feeding stuff deterioration and that mold development at normal temperatures is dependent upon the relative humidity of the interseed air.

2 The dew-point depression directly indicates the relative humidity of a given water-vapor condition in an air and water-vapor mixture.

3 Therefore, "degrees depression" can directly give the moisture condition in the hygroscopic moisture range of a grain-air or other material mixture.

4 A simple, homemade dew-point moisture indicator is described, and some typical performance data for this simple type of instrument are given.

5 Experience with this instrument to date indicates that it should find good use in the hands of laymen as a grain moisture condition indicator. It is believed that accuracy in field usage may be held easily to within ½-deg depression, or if the samples are placed in containers overnight before being read, accuracy can be held to within ¼ deg. In the storage moisture range, this is less than ¼ per cent of grain moisture content. With refinement and proper control, this type of instrument may give high accuracy for experimental work in a laboratory.

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Automatic Controls for a Poultry Laying Battery

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THIS paper reports a commercial engineering research and development project, the aim of which was to promote the effective use of normally wasted overhead farm building space by the installation of income-producing mechanisms, and to study the practicability of reducing the manual labor required in the care of poultry by the use of electric power and automatic electric controls.

To facilitate study of the problems involved, a pilot-model laying battery was constructed in which the hens could be kept in individual cages at different levels and in different vertical groups. With this arrangement, the feeding, watering, egg collecting and droppings removal require transportation control in a vertical as well as a horizontal direction. As a tentative goal, it was desired to develop a model battery wherein no manual attention would be required for a week or longer at a time.

THE GENERAL DESIGN

The pilot battery has conventional cages in which the floors slope toward the front to facilitate the rolling out of the eggs. Conveyor belts are used throughout for moving the feed, eggs and droppings locally at the various levels. To effect cross movement of materials for assembly at a common repository, transverse conveyor belts are employed. Figs. 1 and 2 show the general arrangement of the belts as they are positioned for egg collection and droppings removal. With this scheme, the expansion of the conveyor-belt battery can be indefinite in extent both horizontally and vertically. The use of automatic clutches preserves the desirable feature of independent local conveyor-belt operation.

All-purpose, dry mash feed is delivered on conveyor belts between the backs of each two rows of cages. Feed elevation to the different conveyor belts is accomplished by means of a vertical, bucket-type elevator capable of discharging the feed at any one of several levels. Watering is done by drinking cups located so that birds in two adjacent cages can drink from the same cup.

CONVEYOR BELT OPERATION AND CONTROL

Power Train. A single motor is used to drive all the conveyor belts in a particular category — feeding, egg collecting, or droppings removal. Fig. 2 shows how mechanical power is transmitted from the drive motor 265 to the conveyor belt levels above and also to the cross conveyor belt 223. Clutches are located at sheave positions 275, 276, 277 and 278.

The cross conveyor belt serves two functions. It acts to transport material discharged from any or all the local conveyor belts above, to a point at the far side of the battery. At the same time, it drives speed reducers located below other vertical groups of local conveyor belts (B, C and D, Fig. 1). These latter speed reducers act in the same way as the second speed reducer of Fig. 2 to drive the clutches of the local conveyor belt levels above.

The "Autopos" Clutch. The clutch that was developed to control conveyor belt movement is designed with parts that can be assembled to make the sheave either the driving or the driven element. In addition, the parts may be reassembled to allow reverse-clutch rotation, the use of larger diameter sheaves, sheaves with larger or smaller V-belt grooves or shaft bores, and actuating-tripping mechanisms located in any of the four horizontal quadrants around the clutch. A light-duty (approximately 5-w) a-c solenoid having a pull of 5 oz at $\frac{1}{4}$ in is used to engage the clutch.

Selective Belt Movement. To move a local conveyor belt (Figs. 1 and 2) independently of all other belts of the same

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Houston, Tex., June, 1951, as a contribution of the Farm Structures and Rural Electric Divisions.

The author: STANLEY J. OTIS, engineer, United Industries, Madison, Wisconsin.

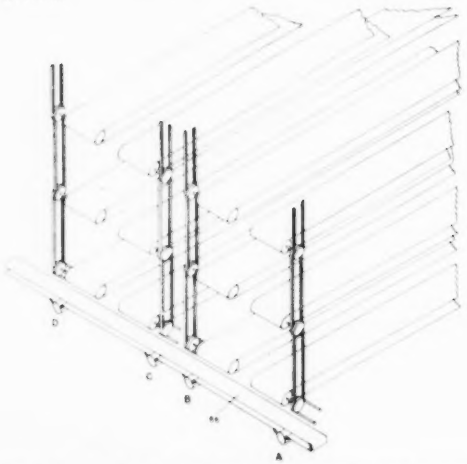


FIG. 1. Horizontal and vertical power train to conveyor belts arranged in multiple. Roller at position A is driving roller for the cross conveyor belt and corresponds to roller 269 in Fig. 2. Rollers at positions B, C and D are driven by the cross conveyor belt, and drive conveyor drive rollers in group above, in the same manner as shown in Fig. 2.

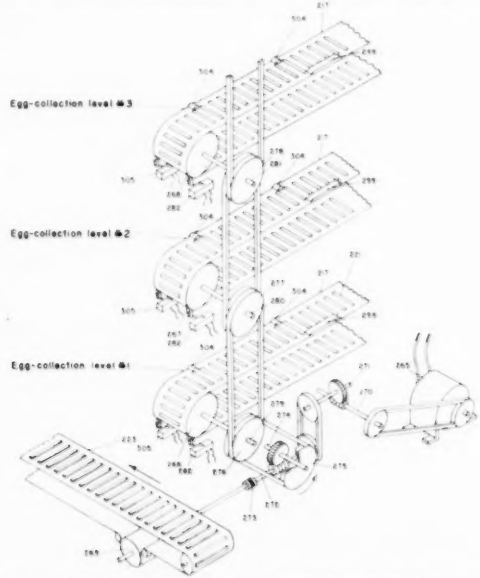


FIG. 2. Detail of power train to vertical conveyor belt group. Automatic "Autopos" clutches are located at sheave positions 275, 276, 277, and 278. At sheave position 275, driving element of clutch is secured to shaft 274. At sheave positions 276, 277, and 278, driving element of clutch is secured to the respective sheaves.

category, the drive motor is started thereby causing the cross-conveyor belt 223 (or 86) to move. By actuating the speed reducer clutch at the bottom of the group in which the particular belt is located, the sheaves of all the local clutches above are made to rotate in an idling condition. The actuating of the clutch for the particular belt then effects the desired movement.

FEEDING

Vertical Elevation. A vertical bucket-type elevator mechanism transports the feed from a hopper at the bottom of the unit up to the various discharge levels. Feed entering the hopper by gravity from the storage bin accumulates near the forward section of the hopper so that each bucket, as it scoops up a load of feed, exerts a lifting action on the supply and does not tend to pack it down into the bottom of the hopper.

Selective Level Discharge and Conveyance. When the feed on the feed conveyor belt at a particular level is to be replenished, the belt commences to move away from the feed elevator at the same time that the elevator buckets start to move upwards and to trip and unload at the same level (Figs. 3 and 4). Excess feed that may have remained on the belt from a previous feeding is discharged into a feed-return chute at the far end of the battery. From here it falls onto a feed-return conveyor belt at the bottom of the battery where it is delivered back into the feed supply hopper from which the feed was originally elevated by the elevator buckets.

When an elevator bucket discharges at a particular level, it first strikes the edge of a feed-unloading hopper 136 (Fig. 4). The feed falls into the hopper and is prevented from scattering off the belt by the sides of the hopper and a curtain. The hopper sides are sloped at such an angle that as the feed moves out on the conveyor belt it does so in a uniform manner. Feed pushed off a conveyor belt by the feeding hens is directed by baffles onto conveyor belt at the next lower level.

Bucket Repositioning. After an elevator bucket is tripped, it continues upward and travels around the top sheave of the elevator. As the bucket passes around the sheave, it reaches a point where it falls back into its latched position.

WATERING

Cup Design and Arrangement. Drinking cups are of a conical shape and are arranged as shown in Fig. 5. Cups at each level are located directly below or above corresponding cups at the other levels.

Flushing. When a fairly large amount of water flows into each of the top-level cups, the attached goosenecks become siphons. Water and debris are sucked out of the top cups and discharged into the cups below. The flushing action repeats itself through all the cups in each vertical group and results in all the waste water eventually being emptied into a common drainpipe. This chain reaction flushing continues as long as sufficient water flows into the top cups.

Filling. To refill the cups, a small amount of water is directed into the top-level cups and is controlled by valves 194 so that it is not flowing at a rate to cause flushing. After the water has filled these cups, it trickles through the goosenecks into the cups below. This process is repeated at the lower levels for all the cups in each vertical group. When the bottom cups have been filled, the overflows spill down into the drainpipe. At this time, the supply to the top cup is cut off.

EGG COLLECTION

Cage Discharge. As in conventional laying batteries, the sloping floor of the cages is designed to facilitate the rolling out of the eggs after they are layed. Experience seems to show that an egg does not stay inside a cage for very long because a hen, in her attempts to set, moves it around and helps to roll it out.

Local Conveyance. At periodic intervals, each egg-collection conveyor belt starts up and moves the eggs on it to the far end where they fall directly onto the cross conveyor belt or into an opening of the egg-lowering chute. When one belt has been cleared, it stops and the belt on the next level starts up. For each egg-collection period, all egg belts of the battery are cleared in the same sequence.

Egg Lowering. Eggs collected from cages above the first level are lowered to the cross-collection conveyor belt by means of a sponge-rubber lined zigzag egg chute. Openings into the chute are made at each egg collection level and all local collection belts in one vertical group discharge onto the same spot on the cross-collection conveyor belt. This type of chute lowers the eggs rapidly and quietly and has proven quite satisfactory in actual operation.

Grading by Weight. At the far end of the cross-collection conveyor belt, the eggs fall onto a padded platform and are slowly drawn over the trays of the egg-weighing mechanism.

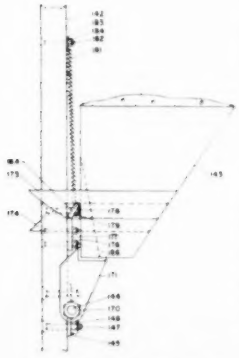


Fig. 5. Vertically rising feed bucket in latched position.

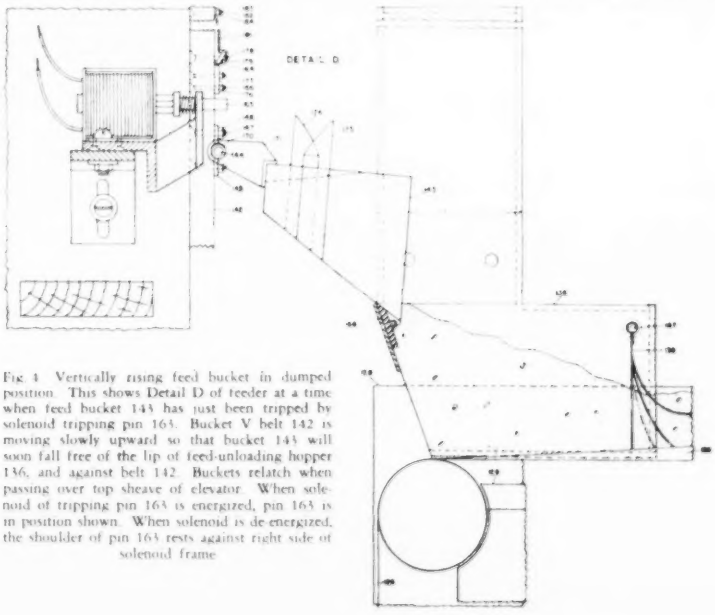


Fig. 4. Vertically rising feed bucket in dumped position. This shows Detail D of feeder at a time when feed bucket 143 has just been tripped by solenoid tripping pin 163. Bucket V belt 142 is moving slowly upward so that bucket 143 will soon fall free of the lip of feed-unloading hopper 136, and against belt 142. Buckets relatch when passing over top sheave of elevator. When solenoid of tripping pin 163 is energized, pin 163 is in position shown. When solenoid is de-energized, the shoulder of pin 163 rests against right side of solenoid frame.

When the egg reaches the tray corresponding to its weight, it drops down onto the moving conveyor belt floor of the egg repository.

Egg Assembly. From the grader, an egg falls into one of the five compartments of the egg repository. These compartments are for storing eggs of five different weights — jumbo, extra large, large, medium and small. The floor of each compartment consists of a conveyor belt having the same width as the compartment. All five repository conveyor belts move slowly away from the grader during the time the egg-collection system is functioning. An egg falling into the forward end of a repository compartment is carried slowly back until it contacts the back wall of the compartment, or another egg already in the compartment. Here the egg slips and rolls on the belt until the egg-collection system is shut down or until the egg is removed by hand.

Production Recording. Two electric counters for each cage are used to record an individual hen's production. One counter records the number of jumbo, extra large and large eggs produced over a period of time while the other counter records the medium and small eggs produced over the same period of time. Totalizing counters give the two counts for all the cages in the battery. With a different relay and more electric counters, the production of a hen could be recorded for all five of the weight grades.

DROPPINGS REMOVAL

Transportation. A wide conveyor belt extending the length of the battery under each row is used to move the droppings at the local levels. A cross conveyor belt functions to collect the lowered material from below each vertical group of local belts and to transport it to a central storage or bagging point at the far side of the battery.

Drying. The entire droppings-removal operation is based on the premise that the material can be satisfactorily dried and transported in a granular state after leaving the local conveyor belts. Air drying at room temperature is assumed for the first stage and heat-lamp drying for the second stage. Although not included in the pilot-model battery design, forced circulation of the drying air might easily be added.

Scraping and Lowering. As the dried material is carried on the belt, over the end roller, it strikes a belt-wide blade which scrapes it from the belt. The loosened material is funneled into a droppings collection chute where it falls onto the cross conveyor belt at the bottom. The chute is designed to allow its extension to any battery height. Unlike the local egg-collection conveyor belts which are entirely cleared with each operation, the droppings-removal conveyor belts are shifted each day through a space equal to approximately three-quarters of a cage width. This procedure allows the droppings to be fairly well distributed over the belt and to be partially dried before reaching the end of the battery.

At a suitable time after the droppings-removal belts have been shifted, the driers are operated in sequence over the end sections of the belts. Each drier is turned on and off by the settings on the program timer, and no two driers function at the same time.

PROGRAM TIMER

A standard PS-24 program timer, manufactured by the Zenith Electric Co., serves as the heart of the electrical control system. This timer is capable of delivering an impulse to its signal circuit at any five-minute interval. In one day, therefore, it can energize this circuit a total of 288 times. The signal-circuit impulse is the action by which the various control devices on the pilot battery are initially energized. Since each impulse is delivered for only about ¾ min, limit switches and locking-release control circuits are needed to maintain the flow of power to many of the devices after the signal from the program timer has been interrupted.

TRANSFER SWITCH

The Autdelay transfer switch is the device that routes the signal-circuit impulse from the program timer to an independent control mechanism or group of mechanisms, in the desired sequence. For example, let us assume that one of the operating times for the lowest feed belt in a vertical group is 5:00 p.m. At this time, a signal-circuit impulse is delivered by the program timer and is routed through one of the contact points to the transfer switch, to the circuit that controls the feed-elevator motor, the bucket-tripping mechanism and the local conveyor-belt clutch for the lowest level. The feed buckets commence to dump at this level and the conveyor belt carries the feed out and away from the elevator. After about ¾ min, the signal-circuit impulse is interrupted at the timer, but the discharge and conveyance of feed continues at the first level due to the maintenance of energization by the locking-release control circuit. If it takes approximately 8 min to completely fill the feed conveyor belt, the delivery process will continue for another 2 min. At that time, another signal-circuit impulse is sent out by the program timer. However, in order to stop the delivery process, it is desired with this impulse to energize the locking-release *(Continued on page 110)*

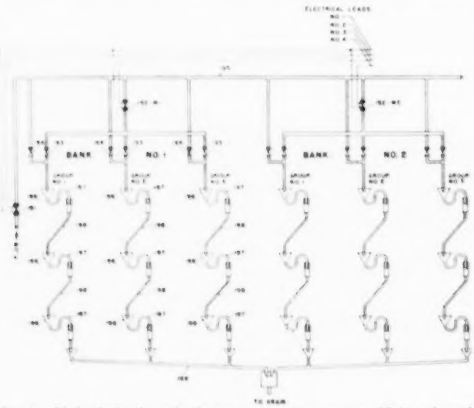


Fig. 5. Multiple-level, multiple-group watering system. Main solenoid valve 191 and flushing solenoid valves 192 are completely closed when in the de-energized state. When energized, these valves are fully open. Hand-operated, flushing-pipe valves 193, and hand-operated, filling-pipe valves 194 are adjusted for proper flow and are not altered thereafter unless the water supply pressure is changed. The electrical leads make connections as follows. No. 1, grounded wire of power supply line; No. 2, contact point of transfer switch and load side of contacts for watering relays No. 1 and No. 2; No. 3, contact point of transfer switch; No. 4, contact point of transfer switch.

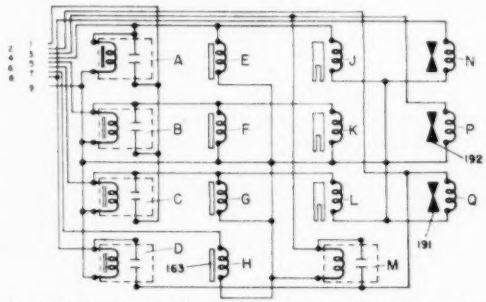


Fig. 6. Electrical-control diagram for automatic feeding and watering mechanisms. A, B and C, feeder relays for levels Nos. 3, 2 and 1, respectively. D and M, watering relays for banks Nos. 1 and 2, respectively. E, F and G, solenoid tripping pins for feeding levels Nos. 3, 2 and 1. H, no-feed solenoid tripping pin. J, K and L, "Autopos" clutch for feeding levels Nos. 3, 2 and 1. N and P, solenoid flushing valves for watering banks Nos. 1 and 2. Q, main solenoid valve for water supply. Electrical leads: 1, to transfer switch contact and to feed-motor controller operating coil; 2, 3, 4, 5, 6, and 8, to transfer switch contact; 7, to hand-operated switch; 9 to ground connection.

NEWS SECTION

Mid-Central Section Meets March 8

THE Mid-Central Section of the American Society of Agricultural Engineers will hold its yearly meeting on Saturday, March 8, in the new Town House in Kansas City, Kans. The forenoon session will be devoted to the general subject of soil and water management and the afternoon session to the drying of farm crops.

The forenoon program will open with showing of pictures of the 1951 Kansas flood furnished through the courtesy of the U.S. Army Corps of Engineers of the Kansas City district. This will be followed by a symposium on the 1951 flood with subjects and speakers as follows: Storm intensities and patterns, by Vern Alexander, U.S. Weather Bureau; surface runoff from the basins, by a representative of the U.S. Geological Survey, watershed programs in relation to 1951 flood damage, by Kirk Sandall, U.S. Soil Conservation Service, and future programs based on recent flood flows, by a representative of the Army Corps of Engineers in the Kansas City district. The closing number on the forenoon program will be on the subject of making machines and terrace systems more compatible, by J. F. Schrunk, University of Nebraska.

The business meeting of the Section will follow the technical program.

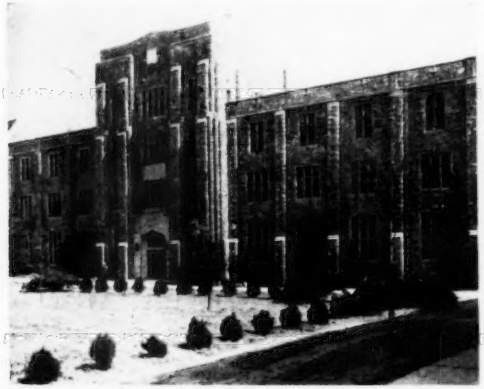
The afternoon session will open with an address by the President of ASAE, Stanley Madill, executive engineer, John Deere Waterloo Tractor Works. This will be followed by a panel discussion on the harvesting and drying of high-moisture corn, wheat and legumes. M. F. Arms, University of Nebraska, and G. E. Fairbanks, Kansas State College, will discuss the subject of harvesting; E. C. Fenton, Kansas State College, and G. M. Petersen, University of Nebraska, will report on the results of drying research, and J. G. Andros, Butler Mfg. Co., and Ray Arndt, Habco Mfg. Co., will discuss new equipment for crop drying.

The meeting will close with a report and discussion on progress on arrangements for the ASAE annual meeting to be held in Kansas City, June 16 to 18 of this year.

VPI Curriculum Accredited

WORD comes from C. E. Seitz, head of the agricultural engineering department, Virginia Polytechnic Institute, that the curriculum there in agricultural engineering has been approved by ECPD.

A curriculum in agricultural engineering leading to the degree of bachelor of science in agricultural engineering, was first offered at VPI in 1913. In 1920 a department of agricultural engineering was organized. At that time only five of the state colleges had professional curriculums in agricultural engineering. VPI was the first college east of the Mississippi to offer such a curriculum. The VPI agricultural engineering department has had a healthy growth; from five staff members in 1922, the staff has grown to 13 active or affiliate members at the beginning of 1952. Until 1949, the curriculum was administered by the dean of agriculture, but beginning with the 1949-50 session, it was placed under the joint administration of the dean of engineering and the dean of agriculture, with degrees granted in the engineering college.



This is the agricultural engineering building at Virginia Polytechnic Institute. It has about 51,000 square feet of floor space and provides classrooms, laboratories and offices. In the rear and adjoining it is a one-story structure that houses the research laboratory, the farm machinery laboratory, and the farm shop.

ASAE Meetings Calendar

February 16—MICHIGAN SECTION, Dearborn Motors Corp., Birmingham, Mich.

March 8—MID-CENTRAL SECTION, Town House, Kansas City, Kans.

March 14—WASHINGTON (D.C.) SECTION, Room 6962, South Bldg., USDA, Washington.

March 21—OHIO SECTION, Ives Hall, Ohio State University, Columbus.

April 4 and 5—VIRGINIA SECTION, Natural Bridge Hotel, Natural Bridge, Va.

April 10 and 11—PENNSYLVANIA SECTION, Agricultural Engineering Bldg., Pennsylvania State College, State College.

April 11 and 12—SOUTHWEST SECTION, Grim Hotel, Texarkana, Tex.

May 16 and 17—ALABAMA SECTION, Gulf Breeze Inn, Gulf Shores, Ala.

June 16-18—45TH ANNUAL MEETING, Hotel Muehlebach, Kansas City, Mo.

December 15-17—WINTER MEETING, Edgewater Beach Hotel, Chicago, Ill.

NOTE: Information on the above meetings, including copies of programs, etc., will be sent on request to ASAE, St. Joseph, Michigan.

In December, 1950, two agricultural engineering staff members passed the examination given by the Virginia State Board for Architects, Engineers and Land Surveyors. In May and June, 1951, four staff members and five agricultural engineering graduates passed the examination. This makes a total of six agricultural engineering staff members who are now registered professional engineers.

A new agricultural engineering building was completed at VPI in 1948. This building now provides space for classrooms, laboratories, and offices and contains 51,000 sq ft of floor space. The three divisions of teaching, research, and extension are accomodated in this building.

Alabama Ag Engineers Tour Plants

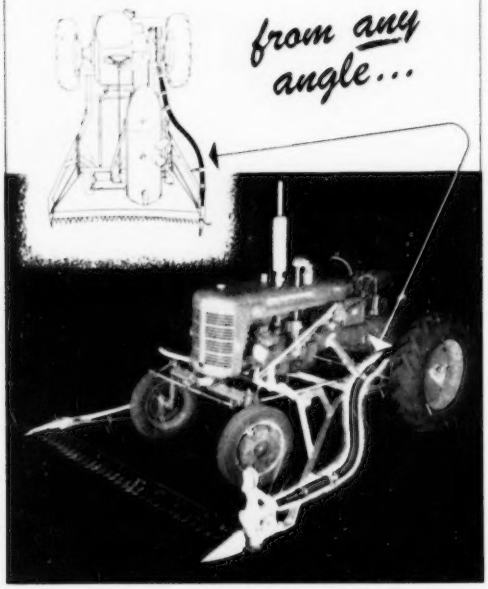
A TOTAL of 71 members and guests of the Alabama Section of the American Society of Agricultural Engineers attended the Section's fall meeting, December 7 and 8, held at Gadsden, Ala. The program of the meeting included three tours and two papers and was climaxed by an inspirational address by Congressman Albert Rains of the fifth congressional district of Alabama.

The tours included the modern steam generating plant of the Alabama Power Co., the Gadsden Works of the Allis-Chalmers Mfg. Co., and the tire, tube and shoe sole plant of the Goodyear Tire & Rubber Co.

(Continued on page 92)

In this picture are shown Section officers and guest speaker at the ASAE Alabama Section meeting, December 7 and 8. (*Left to right*) J. L. Butt, C. A. Rollo, and M. B. Penn, secretary, vice-chairman, and chairman, respectively, Alabama Section; Congressman Albert Rains, dinner speaker, and Harold Schudt, master of ceremonies at Section dinner.

STOW CASE HISTORY



Anvil Front End Mower
Manufactured by Krengel's, Inc., Twin Falls, Idaho

STOW FLEXIBLE SHAFTING

SOLVES POWER TRANSMISSION PROBLEMS . . . BETTER!

The problem: To provide a means of power transmission between power take-off and mower attachment that would give maximum efficiency — eliminate excessive vibration . . . eliminate danger of exposed rotating parts and costly clogging and jamming caused by dirt, grasses. Stow Flexible Shafting *solves* these problems — transmits power smoothly, safely, economically. Put Stow to work on your problems today!

Send for your free copy . . .
Stow Flexible Shafting Bulletin and Torque Calculator.

STOW MANUFACTURING CO.
39 SHEAR ST. BINGHAMTON, N. Y.

Features of the technical program included a summary of supplemental irrigation work in Alabama by Arthur W. Cooper, project supervisor, Soil Conservation Service (Research), U. S. Department of Agriculture, stationed at the Alabama Polytechnic Institute and a talk on supplementing farm income with livestock by a local dairyman, Jerry Roden.

In his address at the Section dinner on December 7, Congressman Rains stressed the challenges facing agricultural engineers by the decreasing farm income, and also pointed out the trend to mechanized farming and the growing demand for food and fiber. Harold Schudt presided as master of ceremonies at the Section dinner.

The officers have decided that the spring meeting of the Alabama Section will be held at Gulf Shores, Alabama, on May 16 and 17, with headquarters at Gulf Breeze Inn.

Owen New Chairman of Hawaii Section

ROBERT R. OWEN, head, agricultural engineering dept., Pineapple Research Institute, was elected the new chairman of the Hawaii Section of the American Society of Agricultural Engineers at the Section meeting on December 12. Warren Gibson, agricultural engineer, Ewa Plantation Co., was elected the new vice-chairman of the Section, and Lawrence W. Larson, assistant agricultural engineer, Hawaii Agricultural Experiment Station, was elected the new secretary-treasurer.

In addition to the business meeting, including the election of officers, the meeting was addressed by Ward Deffenbaugh and Irvin S. Strand, representatives of the sales and service engineering divisions of International Harvester Co. Mr. Deffenbaugh discussed various recent improvements on the engine and transmission of the Company's large track-type tractors, and those present indicated much interest in his description of a proposed all-purpose prime mover for heavy-duty operation such as earthmoving.

In his talk, Mr. Strand dealt with the use of mechanical cotton pickers in southern California, in which he stated that the work by research and extension agricultural engineers of the University of California was invaluable in getting potential users to accept the machine for the picking of cotton. He pointed out that about three-fourths of California's cotton acreage is now picked by machine.

Dr. Ross Moore Discusses Point IV Program

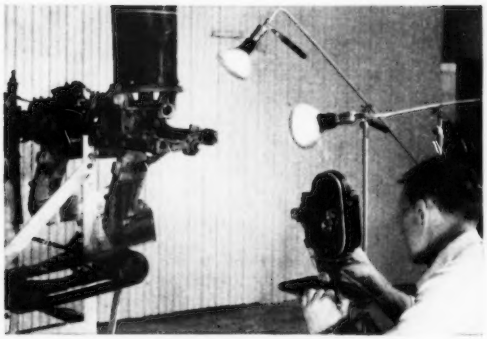
AT THE luncheon meeting of the Washington (D.C.) Section of the American Society of Agricultural Engineers on January 11, Dr. Ross E. Moore, assistant director, Office of Foreign Agricultural Relations, USDA, told how the services of agricultural engineers are being utilized in the Point Four Program. Following a brief review of its historical development, he pointed out that the main work of the Program falls under the Technical Cooperative Administration (TCA) which has three major divisions — Far East, Near East, and Western Hemisphere, and that TCA is responsible for various programs, providing direction of over-all activities in the field of health, education, and agriculture.

(Continued on page 94)

The outstanding newspaper, radio and television coverage of the ASAE winter meeting at Chicago in December was due largely to the efforts of the three men at the left in this picture: Chas. E. Ball, agricultural engineer, Farm and Ranch — Southern Agriculturist," and Arnold R. Daum and Joseph Miller, department of information, American Petroleum Institute. At the right are Richard P. Walker, president, National Council of ASAE Student Branches, and ASAE President Stanley Madill.

A report to you about men and machines that help maintain International Harvester Leadership

How McCormick Planters Earn an "A" for Accuracy



Corn Kernels Star in IH Engineering Movies

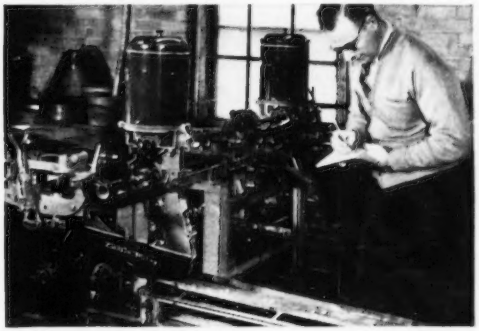
A high-speed movie camera records every kernel movement as corn passes through this glass-sided planter boot. When viewed in slow motion, the film reveals "drop" characteristics that can vary the number of kernels in a hill. These scientific studies help make possible the bull's-eye accuracy of McCormick planters.

Every Seed Plate Must Pass a Tough Exam

A planter can be no more accurate than its seed plates. That's why IH inspectors carefully gauge the center hole diameter of every plate. They also make sure plate thickness doesn't vary from IH standards. Ten additional visual inspections also help to safeguard the seed metering accuracy of McCormick corn planter plates.

Boot Valves are Timed for Accurate Cross Check

Split-second timing is required to accurately check-plant 120 hills of corn a minute. IH inspectors use the gauging device, above, to time the opening of boot valves with the movement of the check fork. They also use this gauge for setting boot valves to open simultaneously for an easy-to-cultivate cross check.



Seed Test Gives Positive Proof of Accuracy

Corn planters, like this McCormick No. 240 two-row, are selected at random from the assembly line and given a planting test. They are set to drop three kernels in a hill at a speed of 120 buttons a minute. In a run of 400 hills, they must "plant" exactly three kernels in 97 percent of the hills, to pass this accuracy test.

INTERNATIONAL HARVESTER

International Harvester products pay for themselves in use—McCormick Farm Equipment and Farmall Tractors . . . Motor Trucks . . Crawler Tractors and Power Units . . . Refrigerators and Freezers—General Office, Chicago 1, Illinois.

FAIR WARNING

to spray equipment manufacturers

In addition to orders already booked for 1952 delivery, we will endeavor to produce for manufacturers of spraying equipment the quantities of pumps shown below, which includes both our standard Series "52" and new International Series I with carbon bearings.

As orders are received, the quantities available of each pump shown here will be reduced accordingly. The monthly production quota detailed below will be insufficient to meet the demand for Oberdorfer spraying pumps during the first half of 1952. Over 50% of our previously unscheduled available production was scheduled in December. If you expect to be shipped any Oberdorfer spraying pumps, be certain to place your order immediately.

SPRING 1952 SPRAYING PUMP PRODUCTION

Pump No.	Pipe Size	Feb.	March	April	May	June
2AX or 2ZX	¼"	350	400	400	200	200
3AX or 3ZX	⅜"	400	350	400	250	250
4AX or 4ZX	½"	1100	1400	700	700	900
7AX or 7ZX	¾"	750	1200	1100	450	500
9AX or 9ZX	1"	900	1000	800	700	450
2000	⅜"	200	150	250	100	125
3000	½"	250	250	0	50	100
4000	½"	400	300	100	0	200
7000	¾"	700	800	400	0	100
9000	1"	900	400	250	0	450

Pump No.	*Price*	*Pump No.*	*Price*	*Pump No.*	*Price*
2AX —	$13.25	4ZX —	$22.00	2000 —	$15.75
2ZX —	17.50	7AX —	22.50	3000 —	20.00
3AX —	15.50	7ZX —	27.75	4000 —	22.25
3ZX —	20.50	9AX —	23.75	7000 —	28.50
4AX —	17.00	9ZX —	29.00	9000 —	29.75

Agricultural Pump Div., Oberdorfer Foundries, Inc.
1422 Thompson Rd., Syracuse, N. Y.

OBERDORFER

BRONZE SPRAYING PUMPS

In citing specific activities of some of the engineers abroad, Dr. Moore pointed out that many of them were more agricultural in nature than being restricted to the specific field of agricultural engineering. He indicated, for example, that an engineer from Arkansas was given training courses in the selection and maintenance of equipment, variety trials, irrigation of rice, selection of land, and served as a general agriculturist. He stated that much service has been rendered by the engineers on the problem of storage of seed and food which is a most important one. Advice has also been given on farm structures, the poultry industry, and soil and water conservation research and development. In closing his remarks, Dr. Moore pointed out that, when engineers or other agriculturists are sent into countries to which the Point Four Program is being carried, each of them tends to do the things which he feels are most needed on the basis of his analysis of the situation. He pointed out that increasing food production in these countries is not enough, but that the people must find better opportunities for health and freedom.

"Human Well-Being Through Engineered Progress"

TO AWAKEN public interest to the prominent part the engineering profession has played in bringing America to its present high economic and social levels, the Centennial of Engineering, to be celebrated in Chicago this year, will shape its activities around the slogan: "Human Well Being Through Engineered Progress."

The thinking behind this slogan was voiced by Dr. Karl T. Compton, chairman, Massachusetts Institute of Technology, when he said: "There is surely a close relationship between the work of engineers and the high standard of living arising from the high per capita production in the United States. Among our professions, that of engineering is outranked in numbers only by teaching and nursing. In no other country is this profession of such high standing. Furthermore, the demand for engineers continually exceeds the supply, and this is because our free-enterprise system gives almost limitless opportunity and very great incentive to make things new and to do things better."

The Centennial slogan will be featured by leading industries during 1952 in all sorts of advertising and in special books and motion pictures being prepared for distribution to the schools and colleges of the country. It will also keynote the exhibit of world-famed engineering accomplishments to be staged at the Museum of Science and Industry in Chicago during the 5-year period starting in mid-1952, including a summer-long pageant also to be conducted at the Museum next year.

Maine Student Branch Active

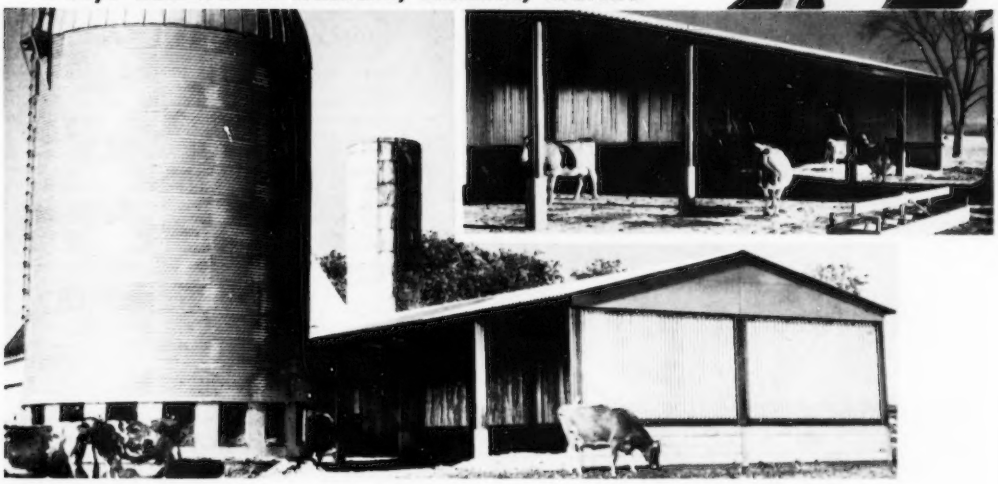
THE Maine Student Branch of ASAE at the University of Maine early in January paid dues for 1952 for 36 Student Members, representing 100 per cent of the eligible students currently enrolled in the agricultural engineering curriculum.

Officers of the Branch are Laurence Smart, Jr., president; David Beppler, vice-president; Rodney Martin, secretary; Henry Cyr, treasurer, and Harry Potter, scribe. Nathan H. Rich is faculty adviser to the Branch and Frank W. Peikert is head of the department.

President greets president. At the left is ASAE President Stanley Madill, executive engineer, John Deere Waterloo Tractor Works, conversing at the 1951 ASAE winter meeting with Richard P. Walker, president, 1951-52 National Council of ASAE Student Branches, and a senior student in agricultural engineering at Louisiana State University.

"Steel buildings are reasonable in cost, safe and permanent"

says **HERMAN E. WINKLER, Lebanon, Indiana**



Here's what Mr. Winkler says about steel buildings on his dairy farm:

"About two years ago I contracted for the erection of a steel building to be used as an implement shed at my Green Ridge registered Guernsey farm. The installation was satisfactory for the purpose because it was obviously fireproof, verminproof, and will require a minimum of maintenance. I also ordered a steel building recently when I wished to change my dairy barn arrangement from a typical stanchion barn to a tramp shed milking parlor layout.

"The steel building which I am using for a tramp shed is 30′ x 80′ enclosed on three sides only and raised from the concrete slab 32". The reasons which appealed to me on the tool shed are the same for my purchase of the tramp shed. Steel appears to me to be the practical and modern building material—reasonable in cost, safe and permanent."

Check carefully, and you'll find that steel buildings are your best buy, whether you need cattle housing, a machinery or hay storage building or an all-purpose structure.

Steel is the strongest building material you can buy for your farm.

SEND THE COUPON FOR FURTHER INFORMATION

Agricultural Extension Bureau
United States Steel Company
Room 4346, 525 William Penn Place
Pittsburgh 30, Pa.

Please send me free literature about steel farm buildings. Building will be used for

Approximate size or capacity .....
Send information to:

Name .....

Address .....

County ..... State .....

United States Steel Company is a steel producer, not a steel fabricator. Your request, therefore, will be sent to building manufacturers who fabricate steel buildings for farm use.

U·S·S Galvanized Steel for Farm Buildings

You get more for your money when you build with Steel

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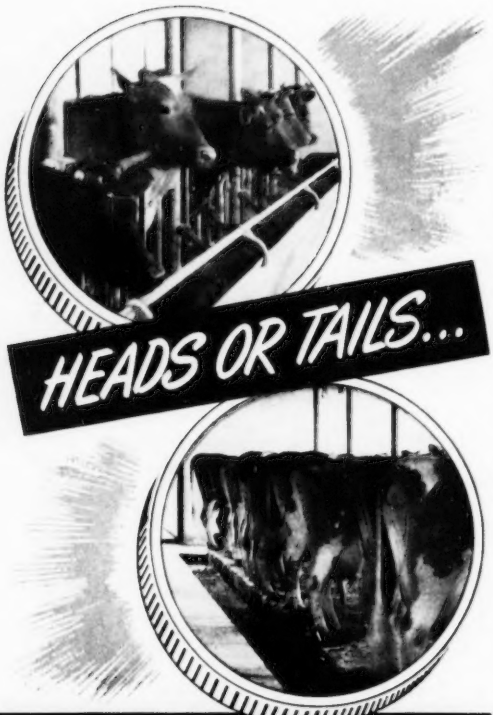
UNITED STATES STEEL



The farmer wins both ways with

CONCRETE DAIRY BARNS

Concrete dairy barns are profitable because they lower feed and labor costs and result in higher milk yields. They are cool in summer, warm and weathertight in winter, verminproof and easy to clean at all times.

Moreover, concrete can't burn or decay. Its reasonable first cost and lifetime service with minimum maintenance add up to ***low annual cost.*** That's why thousands of successful farmers are using concrete, not only for barns, but for milk houses, feeding floors, barnyards, watering tanks and other improvements.

Free illustrated literature is available to assist agricultural engineers in helping farmers to bigger profits by designing and building firesafe concrete dairy barns and many other profitable structures. Literature is distributed only in the United States and Canada.

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NECROLOGY

ADAM T. HOLMAN, extension agricultural engineer (BPISAE), U.S. Department of Agriculture, passed away January 20, 1952, at his home, Cherry Walk Farm, Bowie, Md. He had suffered from a heart condition for some time, especially since his return from the winter meeting of the ASAE in December. The seriousness of his illness was not appreciated so that his demise came as a great shock to his many friends. He was buried at his boyhood home in the Foutz Valley, Pa.

He is survived by his widow, Mrs. Ellen McCarthy Holman, a son, Edward B. Holman, and a daughter, Ellen D. Holman, all of Bowie; two other sons, Adam T. Holman, Jr., with the Army in Honolulu, and John T. Holman, a student at Virginia Polytechnic Institute, and another daughter, Mrs. Leo A. Hovde, Cherry Point, N. C.

Mr. Holman attended Carson Long Institute in Bloomfield, N. J., of which he was a trustee at the time of his death. He received his degree in agricultural engineering in 1922 from Pennsylvania State College. Following graduation he managed a large plantation in South Carolina until 1927, when he joined the North Carolina Agricultural Extension Service as agricultural engineering specialist. In 1932 he entered the Bureau of Agricultural Engineering and was placed in charge of the engineering research carried on at the Bethany, Mo., soil conservation project. In 1935 he was transferred to the newly established Soil Conservation Service. During this period he spent some time in Puerto Rico, formulating a basic plan for soil conservation program.

In 1936 he returned to the Bureau of Agricultural Engineering to take charge of the extension activities in agricultural engineering. In this assignment Mr. Holman represented the Bureau in coordinating the work of the state agricultural engineering specialists with the federal extension service and was charged also with the responsibility of bringing new developments in research to the attention of the extension people and of keeping research engineers advised of the problems in engineering as they appeared to extension workers. Because of his sound basic training, his extended experience with both research and extension activities, and because of his cooperativeness and sound judgment, he made a contribution to agricultural engineering which will continue to bear fruit for many years to come. Over and above his professional attainments, Adam Holman had those qualities of heart and mind which endeared him to all those with whom he came in contact. Admired for his professional attainments, he was loved by all those who knew him intimately.

• • •

JOEL R. BENJAMIN, president, Water Management, Chagrin Falls, Ohio, passed away in December of injuries received in an explosion at the plant of the Austin Powder Co. He was engaged in a research project there at the time of the accident.

Born at Waterloo, Ind., in 1890, he had studied at B. L. Phillips University in 1915; received an AB degree at Bethany College in 1917 and an MA degree at the University of Kentucky in 1929. More recently he had completed supplementary studies in the fields of wild life management and agricultural engineering at Ohio State University. During the past several years he had operated a private contracting business specializing in the building of artificial lakes and streams.

An ordained minister of the Disciples of Christ denomination, he had served as an army chaplain during World War I. At the time of his passing he was a member and deacon of the Federated Church of Chagrin Falls, member of Rotary, and of the Cleveland Farmers Club. Surviving are his wife, Dorothy, a teacher in the Newbury school system, and a son, Lieut. Roger B. Benjamin, presently serving in Korea.

• • •

ARTHUR G. TYLER, assistant professor of agricultural engineering at the University of Minnesota until his retirement in 1950, passed away October 26, 1951, after three months' illness.

Born February 14, 1882, in Reed City, Mich., he received preparatory schooling at Grand Rapids, Mich., high school and completed his undergraduate work at Michigan State College in 1910 with a bachelor of science degree in mechanical engineering.

Following graduation he worked in various engineering lines, including drafting, machine design, bridge work, and railroad engineering. He joined the staff of the University of Minnesota in 1918 as an assistant professor in agricultural engineering. His research at the University included work in rural lighting, rural sanitation and water supply, heating and lighting, hydroelectric farm plants, farm building ventilation, wind power electric lighting plants and other rural, farm and home conveniences.

In addition to his university classes, he taught physics and farm and home conveniences to students at the University's school of agriculture, finding time to do research along with a full teaching schedule. He also was a frequent contributor to Minnesota agricultural engineering news letter and other technical farm periodicals. He had been a member of ASAE since 1919.

He is survived by his wife and his mother, Mrs. Bertha Peck, both of St. Paul; a daughter, Mrs. Marjoria Rubis of Washington, D.C., and two grandsons.

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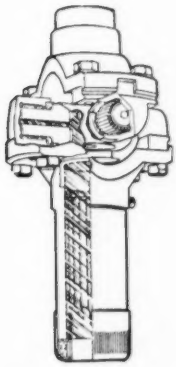
MECHANICS joints are designed to permit generous, long-lasting lubrication — without disassembling. One "shot", through a convenient oil plug hole in the cross, fills the reservoir from which the lubricant is forced to all four bearings, equally. Another "shot" fills the slip-yoke chamber. Thoroughly efficient seals prevent leakage and keep out dirt and moisture.



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Applicants for Membership

The persons listed below have applied for admission to membership or for transfer of membership grade, in the American Society of Agricultural Engineers. Members of the Society who wish to commend or object to any of these applicants, should write the Secretary of the Society at once. If there are no objections, and if confidential statements furnished by their references are satisfactory, these applicants will be voted on by the Council after March 15, 1952.

ACKLEY, JOHN W.—Jr. engr., product dev. dept., Deere & Co., Moline, Ill.

ALDRICH, HARLAN W.—Agr. engr., Tri-County Elec. Co-op., Carrington, N. D.

ANDREWS, ROBERT JR.—Agr. eng. asst. to branch mgr., John Reiner & Co., Syracuse, N. Y.

BAKER, JACK W.—U.S. Army. (Mail) Box 209, Navasota, Tex.

BERGERON, ALBERT J., JR.—Asst. air installations officer, U.S. Air Force. (Mail) Hillcrest Apt. A-2, Pineview St., Shelbyville, Tenn.

BILANSKI, WALTER—Student, Ontario Agricultural College, Guelph, Ont., Canada.

BLAND, HAL E.—Asst. agr. engr., South Carolina Agr. Exp. Sta., Clemson, S. C.

BOURNE, WILLIAM J.—Farmer, Netherhill, Sask., Canada.

BROOME, CHARLES L.—Owner, Tractor & Liquid Fert. Co., Prentiss, Miss.

BROWN, ROBERT C.—Agr. engr., Soil Conservation Service, USDA, Greenville, Tex.

CARLSON, ELVIN L.—Project officer, U.S. Air Force. (Mail) 525 S. Cedar, Apt. B, Albuquerque, N. M.

CARLSON, NORMAN T., JR.—Project engr., eng. dept., Allis-Chalmers Mfg. Co., La Porte, Ind.

CARPENTER, WALTER F.—Agr. engr., Sargent Roundy Corp., Randolph, Vt.

CASTOR, JERE G.—Project engr., Sundstrand Machine Tool Co., Rockford, Ill.

CAVANAUGH, JOHN P.—Box 38, Velva, N. D.

CHAFFEE, ARTHUR W.—Graduate student, Ohio State University, Columbus, Ohio.

CHAUDHARY, I. A.—Sales engr., Buckwell & Co., Ltd., Lahore, Pakistan.

CLARK, DONALD E.—Trainee, Massey-Harris Co., Ltd., Toronto, Ont., Canada.

DEARDORFF, HUGH A.—U.S. Army. (Mail) 523 Kansas Ave., Holton, Kans.

DENMARK, RICHARD S.—Asst. mgr. and engr., Equipment Sales & Service, Ft. Pierce, Fla.

DENNELER, DANIEL R.—2nd Lt., U.S. Army, TAS P O 1488, Ft. Bliss, Tex.

DICKENS, JAMES W.—Res. instr., Border Belt Tobacco Res. Farm, Whiteville, N. C.

DIMICK, NIEL A.—Asst. agr. engr., South Dakota State College, Brookings, S. D.

DRAGON, WALTER J.—Asst. branch mgr., Strazzullz Bros. Co., Buffalo, N. Y.

EBBINGHAUS, JAMES H.—U.S. Air Force. (Mail) R R 4, Lebanon, Ind.

EDEN, CARROLL L.—Engr., Buchanan County Rural Elec. Co-op., Independence, Iowa.

EGGLETON, CECIL H., JR.—Graduate fellow in agr. eng., Michigan State College, East Lansing, Mich.

EISENWINTER, CHARLES E.—Tool maker, Cameron Iron Works, Houston, Tex.

FENTON, RICHARD S.—Trainee, The Oliver Corp., Plant No. 1, South Bend, Ind.

FINEMAN, ABRAHAM—U.S. Air Force. (Mail) North Branch, N. J.

FISCHBACH, PAUL E.—Agr. dev. agent, The Central Nebraska Public Power & Irrigation Dist., Holdrege, Nebr.

FLEMING, JOSEPH T., JR.—Irrigation engr., Cullander Machinery Co., Belzoni, Miss.

FULMER, ROBERT A.—U.S. Air Force. (Mail) Belvue, Kans.

GARBER, H. JOHN—Hydraulic engr., U.S. Bureau of Reclamation, USDI, Chico, Calif.

GEORGE, HAROLD W.—Mason City, Nebr.

GORDON, ROBERT E. M.—Land inspector, dept. of lands and forests, Land Utilization Res. & Survey, Victoria, B. C., Canada.

GOSS, JOHN R.—Graduate student, University of California, Davis, Calif.

GRAY, WAYNE T.—U.S. Army. (Mail) 16181 Lindsay, Detroit 35, Mich.

GRIFFITH, C. LYNDON—Farmer, Box 428 Elkhart, Kans.

GROSE, LAWRENCE L.—Sales engr., welder div., Lincoln Elec. Co. of Canada, Leaside, Ont., Canada.

GROUWINKEL, FRANKLIN—Hydraulics engr., Douglas Aircraft. (Mail) c/c Steve Brooks, R R 3, Ames, Iowa.

GUPTA, S. B.—Mechanical engr., Central Tractor Org., Govt. of India, New Pusa, New Delhi, India.

HAMM, JOSEPH G., JR.—Trainee, International Harvester Co., Jacksonville, Fla.

HANSEN, FREDERICK P.—Parts man, F. S. Bidwell Co., Windsor Locks, Conn.

HARDEN, WILLIAM G.—Farmer, R R 1, Zebulon, Ga.

HAUPT, CORTLAND O.—Belmond, Iowa.

HAZLE, RICHARD W.—Foreman, Pierson Orchards, Ionia, Mich.

HEBBLETHWAITE, PETER—Graduate res. asst., Michigan State College, East Lansing, Mich.

HOBBS, ERNEST H.—Agr. engr., Dominion Exp. Sta., Lethbridge, Alta., Canada.

(Continued on page 100)

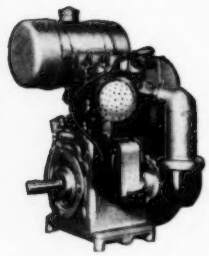
POWER TO FIT THE MACHINE — POWER TO FIT THE JOB

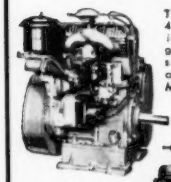
WISCONSIN-POWERED
Mulch-Vac Sweeper

Picking up leaves and mulching them is the task of this Wisconsin-powered Mulch-Vac Sweeper, manufactured by Atwater-Strong Company, Atwater, Ohio. It covers as much as six acres of lawn per day and also can bag leaves along with debris such as newspapers, paper cups, boxes and cigarette butts.

This is another typical Wisconsin Engine application, from the standpoint of *ideal power to fit both the machine and the job*. The lawn sweeper illustrates once again the widespread variety of work handled by Wisconsin Air-Cooled Engines in powering the majority of equipment in the 3 to 30 hp. range. Such features as tapered roller bearings at both ends of the shaft, taking up all thrusts; in-built dependability throughout; foolproof AIR-COOLING and an easily-serviced OUTSIDE magneto with impulse coupling for any-weather starts . . . provide the power you can recommend confidently . . . power your customers endorse.

Write for detailed information for your power files, covering all models . . . 4-cycle single-cylinder, 2-cylinder and V-type 4-cylinder models.





This Model AKN 4-cycle Single Cylinder Wisconsin Engine (3-6 H. P. supplies dependable power for the Mulch-Vac Sweeper

2-cylinder models, 7 to 13 hp.

V-type 4-cylinder models, 15 to 30 hp.

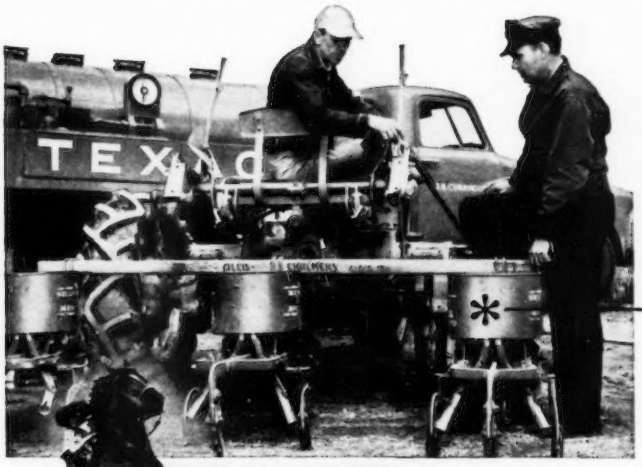
WISCONSIN MOTOR CORPORATION

World's Largest Builders of Heavy-Duty Air-Cooled Engines

MILWAUKEE 46, WISCONSIN

Sows 40 acres a day

With Multiple Vetch Planter

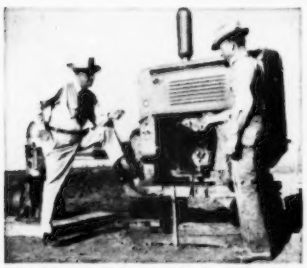


Mr. Joe E. Lewis (left), who farms 360 acres near Sikeston, Missouri, shows Texaco Man W. B. Cunningham multiple vetch planter he put together for about $6.00, not counting the cost of the individual planters.

Mr. Joe E. Lewis, near Sikeston, Missouri, hit on the happy idea of saving time, labor and fuel by mounting three individual vetch planters on a crossbar behind his tractor. With his multiple planter, Mr. Lewis can sow 40 acres a day.

Mr. Lewis has also discovered that *it pays to farm with Texaco Products.*

Rita Jean Lewis, eight-year-old daughter of Mr. J. E. Lewis, puts her horse "Bill" through the paces for Texaco Man W. B. Cunningham.



Working night and day for 10 days at a time, the motor of this water pump gives Havoline Motor Oil a real workout. But Mr. Bill Dooley (right), near Lubbock, Texas, finds Havoline stands up. Havoline is ideal for gas or Diesel engines because it exceeds Heavy Duty requirements. Texaco Man Lloyd Tucker is visitor on left. Mr. Dooley's irrigation system makes possible a bale of cotton per acre.

Mr. George Tinkham (left), near Cape Charles, Va., irrigates his truck farm, using easily movable aluminum pipes to carry the water. Like Mr. Dooley he uses Texaco Products. He likes Marfak lubricant because it sticks to bearings better and longer, doesn't melt down and drip off, dry up or wash off. It seals out grit and dirt from open bearings. Texaco Man Vernon Martin is shown on right.

Friendly visitors when service is needed: that's what Texaco Men are the country over. Texaco Man Gordon Ebbert (right), of Colfax, Washington, has a friendly word with Dick Haxton, prominent farmer, as he fills the tank with Fire-Chief, the gasoline with superior "*Fire-Power*" for low-cost operation.

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TUNE IN... Metropolitan Opera broadcasts every Saturday afternoon. See newspaper for time and station.

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Texaco Petroleum Products are Manufactured and Distributed in Canada by McColl-Frontenac Oil Company Limited.

Fifty years 50 in Fifty Years

Applicants for Membership

(Continued from page 98)

HOLZ, ROBERT G.—Supervisor in charge of dev. and equipment, Goodyear Eng. Corp., Charlestown, Ind.

HOPKINS, DEAN F.—Res. asst. in agr. eng., University of Illinois, Urbana, Ill.

HOVEY, GEORGE M.—Farmer, R.R. 1, Houlton, Maine.

HOWARD, DAVID R.—2nd Lt., U.S. Air Force, Box 214, San Marcos AFB, San Marcos, Texas.

JACOBSON, WAYNE D.—Trainee, Bettendorf Wks., J. I. Case Co., Bettendorf, Iowa.

JENSEN, MARVIN F.—Graduate res. asst. in agr. eng., North Dakota Agricultural College, Fargo, N. D.

JUTRAS, PIERRE J.—Asst. serv. supervisor, Cockshutt Farm Equipment Ltd., Montreal, PQ, Canada.

KALE, GERALD A.—2nd Lt., U.S. Air Force. (Mail) 111 Shawnee, Hiawatha, Kans.

KEECH, DONALD K.—Design engr., The Oliver Corp., South Bend, Ind.

KELLY, DONALD R.—Graduate student, Kansas State College, Manhattan, Kans.

KENNY, EDDIE F.—Sales and serv., Golightly Motor Sales, W. Monkton, Ont., Canada.

KOHNKE, ROBERT E.—Eng. aide, Soil Conservation Service, USDA, Humboldt, Iowa.

LAURION, ERVIN J.—Production and design engr., French & Hecht, Davenport, Iowa.

LEATHERS, JACK O.—Resident engr., Marbry & Johnson, Inc., Robinson, Ill.

LIPPKE, DONALD F.—Serv. & education supervisor, Bettendorf Wks., J. I. Case Co., Bettendorf, Iowa.

MAIS, DONALD L.—Farmer, Stoneham, Colo.

MARTIN, RICHARD H., JR.—Student, Virginia Polytechnic Institute, Blacksburg, Va.

MCCLUNG, FORREST E.—Eng. dept., City of Ponca City, Ponca City, Okla.

MCLEOD, HERBERT E.—2nd Lt., U.S. Army. (Mail) Rembert, S. C.

MEDLEY, JACKSON C.—Trainee, The Massey-Harris Co., Racine, Wis.

MIGHELL, RUSSELL I.—Trainee, J. I. Case Co., Rockford, Ill.

MILKS, HARLAN P.—Branch mgr., Starline, Inc., Albany, N. Y.

MUTCHLER, CALVIN K.—Res. asst., Ohio Agricultural Exp. Sta., Wooster, Ohio.

MYERS, GLENN I.—Project engr., John Deere Ottumwa Wks., Ottumwa, Iowa.

NEHLS, EDWARD J.—Lt., U.S. Air Force. (Mail) 6040 Whittier Rd., Detroit 24, Mich.

NEWMAN, RONALD E.—Design engr., choremaster div., Lodge & Shipley Co., Cincinnati, Ohio.

NOBLE, CHARLES M.—U.S. Army. (Mail) R.R. 1, Manteno, Ill.

PATTERSON, JOHN A.—Exp. officer, British Society for Res. in Agr. Eng., Scottish machinery testing sta., Howden, Mid-Calder, Midlothian, Scotland.

PAULSON, VERNON N.—In charge of farm implement sales, Russell, Burdsall & Ward Bolt and Nut Co., Chicago, Ill.

PEOPLES, GEORGE F.—Hydraulic engr., Bureau of Reclamation, USDI, Chico, Calif.

POLLAKAS, KALJO—Grout inspector, B. C. International Eng. Co., Nechako, B. C., Can.

POLNICKY, HAROLD S.—Exp. engr., The Oliver Corp., Charles City, Iowa.

POWELL, R. W.—Regional mgr., The Fafnir Bearing Co., New Britain, Conn.

RIVER, DALE A.—Design engr., The Oliver Corp., Charles City, Iowa.

RIVERA, PAUL A.—Agr. engr., Soil Conservation Service, USDA, Santa Fe, N. M.

ROSSEBO, THOMAS T.—Asst. design engr., Rockford Wks., J. I. Case Co., Rockford, Ill.

SCHEUCHZER, EUGENE E.—Servicing engr., Liberty Mutual Insurance Co., Springfield, Mass.

SCHRANK, GILBERT C.—Agr. engr., Soil Conservation Service, USDA, Eden, Tex.

SHAW, BILLY L.—Trainee, Western Cotton Oil Co., Div. of Anderson-Clayton, Inc., Abilene, Tex.

SNAVELY, JOHN E.—Jr. engr., John Deere Waterloo Tractor Wks., Waterloo, Iowa.

STEELE, JOHN W.—Asst. to agr. engr., Northeast Agr. Eng. Service, Hampden, Mass.

STONE, ROGER W.—4001 F, Lincoln, Nebr.

STRATTON, CHARLES L.—Parts sales rep., Hub Motor Sales, Inc., Cortland, N. Y.

THOMAS, KENNETH R.—Jr. engr., product dev. dept., Deere & Co., Moline, Ill.

TOBIASSEN, ARTHUR S.—Jr. engr., Dearborn Motors Corp., Birmingham, Mich.

WEIR, WILLIAM I.—Sales engr., Spramotor, Ltd., London, Ont., Canada.

WEISS, MAX—Production mgr., Brady Mfg. Corp., Des Moines, Iowa.

WELLONS, JAMES F., JR.—Rural rep., Virginia Elec. & Power Co., Williamston, N. C.

WILLIAMSON, RONALD K.—Farmer, R.R. 2, Marseilles, Ill.

WITT, WILMER F.—Asst. engr., Fox River Tractor Co., Appleton, Wis.

WOODRUFF, ALFRED C.—Dist. sales mgr., Mojonnier Bros. Co., Chicago, Ill.

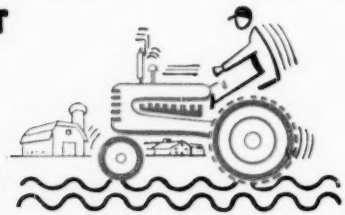
ZAVITZ, FRANK E.—Student, Ontario Agricultural College, Guelph, Ont., Canada.

TRANSFER OF MEMBERSHIP

BOYD, I. I.—Asst. prof. of agr. eng., Cornell University, Ithaca, N. Y. (Associate Member to Member)

EVEN THE MOST

Violent Vibration



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RUGGED

Rochester

GAUGES

Specially designed for heavy-duty service, Rochester Tractor Gauges are built with vibration and pulsation dampeners.

There's no danger of accuracy loss through rough riding. Even high overloads can't damage their sensitive movements, or cause their pointers to flutter. They *keep on* delivering accurate readings, too, year after year, because of their unusually rugged construction.

And for *extra* protection, Rochester gauges are *permanently* sealed behind heavy glass crystals. Dirt and water just can't get in. This outstanding dependability has made Rochester Gauges the choice of all leading tractor manufacturers for more than 35 years.

Rochester Manufacturing Company, Inc.
99 Rockwood St., Rochester 10, N. Y.

ROCHESTER GAUGES

DIAL THERMOMETERS GAUGES AMMETERS

A Line of Water Control Jobs

AND A NEW LINE OF POWER TO HANDLE THEM

40.26 drawbar hp., 11,250 lb.

72 drawbar hp., 18,800 lb.

109 drawbar hp., 27,850 lb.

Hydraulic Torque Converter Drive, 175 net engine hp., 41,000 lb.

● Allis-Chalmers HD-15 'dozing out an 1,800-yd. farm pond in Caldwell County, Missouri. On completion, pond will hold water to a depth of 10 feet.

A contour furrow will hold a raindrop, a terrace will check a rivulet, and a farm pond will stop a gulley. Down stream, large dams complete the job.

All along the line, effective water control depends on moving and re-shaping the earth's surface. Whatever the size of the job, there is a new Allis-Chalmers crawler tractor to handle it.

Every tractor in the A-C line is designed completely new from the ground up. Each sets new standards in its class for performance, strength, ease of operation and servicing. Wide choice of bulldozers — plus a full, modern line of other Allied equipment — match every Allis-Chalmers tractor to the job at hand.

Write for free catalogs describing the newest, finest tractor line on earth, or get the full story from any Allis-Chalmers industrial tractor dealer.

ALLIS-CHALMERS
TRACTOR DIVISION • MILWAUKEE 1, U. S. A.

● Building terraces, clearing land, any soil conservation work is quickly handled by the new Allis-Chalmers tractors. Here the Model HD-9 clears land in Missouri.

It's New...

THE FAR MORE POWERFUL FERGUSON "30"

BIGGER...

in power...in performance...in economy!

Drive it! You'll see what we mean!

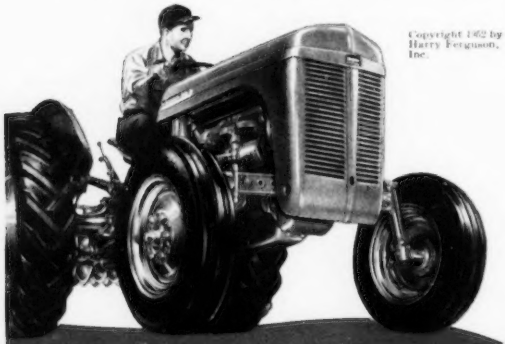
You'll be thrilled by how easily it pulls three bottoms in almost any soil . . . by the way it handles *every* job on your farm from the heaviest to the lightest with speed and efficiency.

As for economy, ask any Ferguson "30" owner!

He'll smile with pride as he talks of his savings in gas, oil and service. "Compare price tags, too," he'll tell you, "for tractors of comparable capacity."

Go see your friendly Ferguson Dealer today. Ask him for a "Showdown" demonstration of the Ferguson "30"... the tractor with the one and only Ferguson System. Find out how it will meet *more* of *your* needs *more* of the time.

Building a better world through better farm mechanization is the business of Harry Ferguson, Inc., Detroit 32, Mich.



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Meets MORE of the needs of MORE of the farmers MORE of the time!

NEWS FROM ADVERTISERS

New Products and Literature Announced by AGRICULTURAL ENGINEERING Advertisers

Timken's Profilograph. How do you go about measuring the smoothness or roughness of a highly polished steel sphere or cylinder? How can you tell whether a machined steel circle is a perfect circle or not? Some time ago The Timken Roller Bearing Company developed a machine which could determine with extreme accuracy just how rough or how smooth a steel surface was. Just recently Timken engineers have added a further refinement to this machine, with which it is possible to determine if a ground circle is perfect or not. (With this new development, both surface finishes and geometry are checked within a millionth of an inch.)

First of all, since we are accustomed to hearing such astronomical figures as billions, when we speak of the national debt, perhaps one millionth of an inch doesn't seem too impressive. What that figure means can be dramatized when it is realized that one millionth of an inch is 16,000 times finer than the thickness of a thin dime. A millionth of an inch is 5,000 times thinner than a single sheet of newspaper.

The name of this phenomenal machine that can measure accurately to within a millionth of an inch is the "Profilograph." This development was directed by the experimental engineer for The Timken Roller Bearing Company. Roughly, it works as follows: The surface of the object to be measured is mounted on a flat, delicately adjusted table which is fitted into a special bearing. A highly refined hinge is mounted just above the specimen for measurement. At the end of this hinge is a diamond needle and a tiny mirror. The diamond needle traces ever so lightly over the surface of the object as the complete table upon which the specimen is mounted turns. As the needle rides over the surface, any variation in that surface wiggles the needle, and also the tiny mirror mounted on the same hinge as the needle. A tiny beam of light is played on the mirror and as the mirror moves, the beam of light moves also. Through a series of other mirrors, the light beam is transmitted onto a photographic film and the variations on the surface of the object being measured are recorded on a circular film. It is this instrument that can tell the initiated just how rough or how nearly perfect are Timken Tapered Roller Bearings. By changing the length of the light beam, surface variations can be magnified up to 5,000 times their actual size.

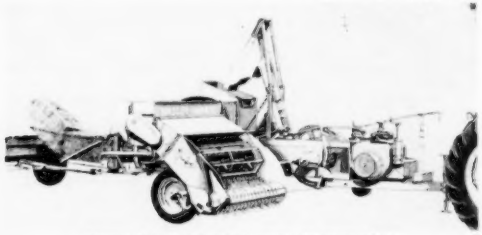
• • •

"Nickel Alloy Steel Castings in Industry" is a 32-page bulletin with over 100 illustrations recently issued by the International Nickel Co., 67 Wall St., New York 5, N. Y. It cites examples, including composition and property data on steel, cast to shape, as a reliable engineering material to meet exacting service requirements and the continued demand of industry for increased power, higher speeds, heavier loads and longer service life in machinery and equipment parts that can be made most economically and efficiently in cast form. Data on properties and applications of cast nickel steels of the constructional grades are classified by industrial fields. Low temperature properties, abrasion resistance, depth hardening and welding are discussed. Advantages and recommended specifications and compositions for typical service applications are given.

• • •

Massey-Harris Baler. The Massey-Harris Co., Racine, Wis., recently announced a new automatic twine-tie slicer baler to produce a sliced bale of proper density with positive automatic tying and minimum leaf loss, and safe for one-man operation. The new baler has a full floating pick-up table ... adjustable by spring tension. Vertical feeder assures positive movement of windrowed hay to the auger trough without the use of raddles or raker bars. Sheet metal under the feeder is solid, preventing loss of leaves. The feeder housing has clearance to handle full flow of hay. An auger conveyor to the bale chamber has balanced capacity to deliver a uniform charge of hay. At the baler chamber, the "wad" packer is adjustable for short or long crops to pack hay or straw to proper density throughout the bale. Steel plunger traveling on a 32-in. stroke, 50 strokes per minute, produces uniform bales. The plunger is equipped with a sheer blade which cuts each charge of hay, producing a "sliced" bale. Plunger action is continuous during tying operation ... does not hesitate or have false stroke. Entire action of

(Continued on page 104)



Massey-Harris automatic, twine-tie slicer baler

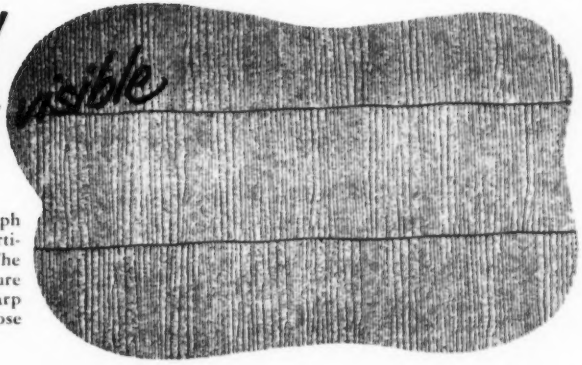
In Beautiful Colors...

Johns-Manville *Smoothgrain* Asbestos Siding

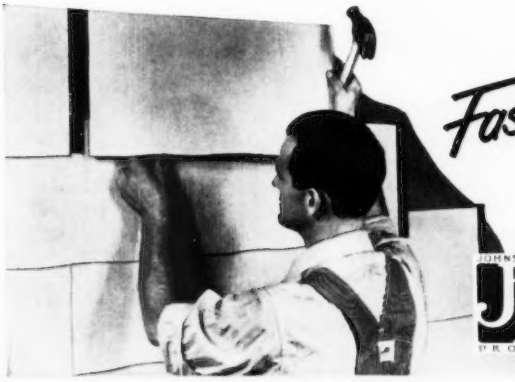
Smooth surface... yet beautifully grained

The surface of this new siding shingle is smooth, not grooved, but from any angle you'll see a richly colored, deep-grained texture that's built right into the shingle with permanent ceramic granules. Because the surface is smooth, Johns-Manville Smoothgrain Asbestos Siding resists soiling; and because it *looks* grooved, they are architecturally attractive. Available in a wide variety of *Permatone* colors including Heather Green, Autumn Brown, Weathered Gray, Silver Gray and White.

Nail heads and joints are hardly visible



In this unretouched photograph there are 18 exposed nail heads and 8 vertical joints but you can hardly see them. The nail heads are lost in the color blended texture and because the edges are cut so clean and sharp each shingle blends harmoniously with those adjoining.



Faster, better installation

Because of the smooth surface and uniform thickness, Smoothgrain Shingles are easier to cut, have cleaner edges . . . there's no chipping to cause spoilage or mar appearance. Fireproof, rotproof, and weatherproof, Smoothgrain Asbestos Siding never needs preservative treatment. Applied right over existing sidewalls, it restyles the oldest house and makes it look "new."

For a full-color brochure on Smoothgrain, write Johns-Manville, Box 290, New York 16, N. Y. In Canada, write 199 Bay Street, Toronto 1, Ontario.

JOHNS MANVILLE JM PRODUCTS

Johns-Manville

NEWS FROM ADVERTISERS

(Continued from page 102)

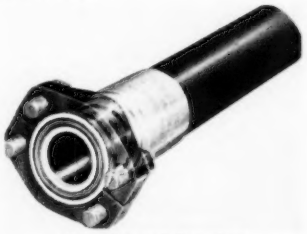
tying occurs at the forward stroke—while the bale is under full pressure. In operation, the baler carries three bales, one ready to drop on the ground, one in the rear of the bale chamber and one being formed for tying. Knotter heads and twine needles are operated by direct drive from the main shaft through gears, timed for placing of cords and tying while the bale is momentarily under full pressure. A fan located in front of knotter heads cleans heads of dust and twine fragments. Conveniently located cans hold four 24-lb balls of baler twine.

• • •

Anchor Split-Flange Clamp. The Anchor Coupling Co., Libertyville, Ill., has announced the development of a new split-flange type hydraulic hose clamp which is easy to use, eliminates threaded joints, and prevents leaks. A wide selection of sizes is available for use with either clamp or pressed-on type couplings in straight or angle styles for one or two-wire braid hose from ½ in through 2 in ID. It can be used for high, medium, or low-pressure service, suction return lines, etc.

The assembly of the Anchor clamp is easy. All that is required is a small, convenient, automotive-type wrench. This means greater clearance, no strain, less effort, and the elimination of thread compounds.

The seal consists of an O-ring which has proven successful in countless hydraulic applications. This static O-ring seal eliminates the need for tapered threads. There is no wedging action to cause distortion in valve bodies, cylinders, or any other piece of hydraulic apparatus. This new Anchor clamp provides a strong connection. The bolt centers are located on the centroid so that any applied forces are equalized. This feature helps maintain a permanent, leakproof seal in the toughest kind of service.



The anchor split-flange clamp

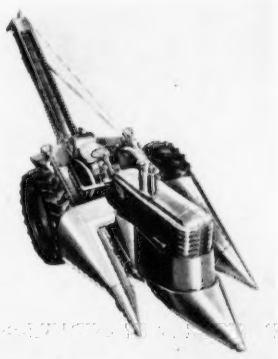
• • •

Massey-Harris Mounted Corn Picker. The Massey-Harris Co., Racine, Wis., has introduced a new 2-row mounted corn picker designed for its model 30 and 44 tractors. A new addition to the Massey-Harris line of farm equipment, it is described as a big-capacity, "drive-in" machine which combines lightweight with rugged construction. The unit is operated through the tractor hydraulic system.

The new mounted picker has most of the weight distributed over the rear wheels of the tractor. The unit weights 2275 lb and has easy mounting features. Two pins, two lift rods, and installation of two springs complete the front hookup. To attach the wagon elevator, hopper and blower, the operator inserts two pins and attaches two rods. Connecting the drive chains, tightening elevator chains and attaching blower belt completes the mounting. Power to the main drive is taken from the belt pulley shaft and runs through a housing under the tractor which also acts as a pivot point for mounting the unit. Drive and housing can be left on the tractor when the picker unit is removed.

Adjustable, full-floating snouts and center divider of the mounted picker are designed to lift corn rapidly . . . outside points are spaced 74 in apart. Gathering chains on the picker are driven through slip clutches to prevent damage to the machine. It has separate, independent snapping and husking rolls. A rubber flight-type elevator in the unit carriers ears across the full length of the husking rolls. Heavy-gage steel pressure plate gives constant tension on ears for efficiency in husking.

Massey-Harris engineers have incorporated in the 2-row mounted picker the same basic design principles previously proven in the self-propelled corn picker.



The Massey-Harris 2-row mounted corn picker

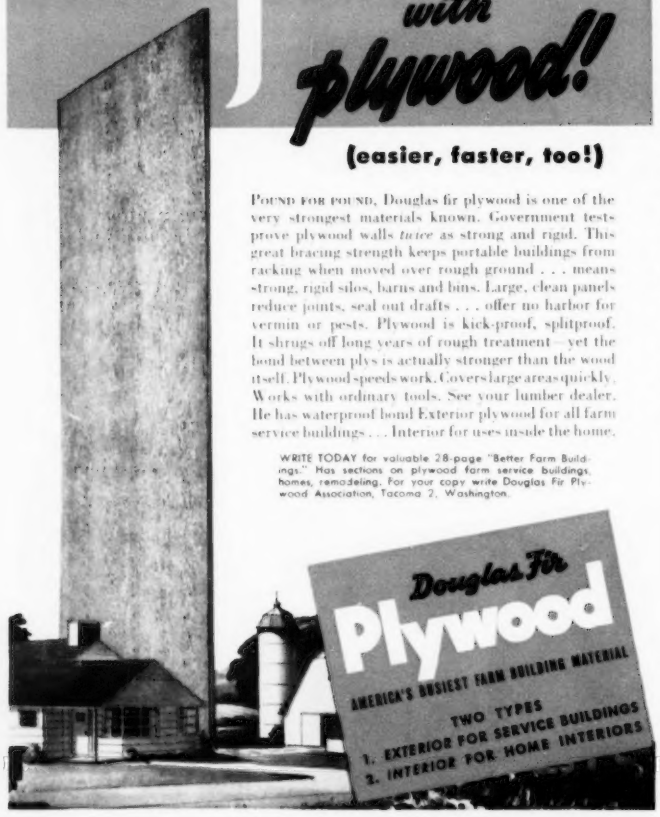
On the Farmstead,
In the Home,
For New Construction,
Remodeling or Repair

You'll build stronger with plywood!

(easier, faster, too!)

POUND FOR POUND, Douglas fir plywood is one of the very strongest materials known. Government tests prove plywood walls *twice* as strong and rigid. This great bracing strength keeps portable buildings from racking when moved over rough ground . . . means strong, rigid silos, barns and bins. Large, clean panels reduce joints, seal out drafts . . . offer no harbor for vermin or pests. Plywood is kick-proof, splitproof. It shrugs off long years of rough treatment—yet the bond between plys is actually stronger than the wood itself. Plywood speeds work. Covers large areas quickly. Works with ordinary tools. See your lumber dealer. He has waterproof bond Exterior plywood for all farm service buildings . . . Interior for uses inside the home.

WRITE TODAY for valuable 28-page "Better Farm Buildings." Has sections on plywood farm service buildings, homes, remodeling. For your copy write Douglas Fir Plywood Association, Tacoma 2, Washington.



TOOLS THAT HELP YOU PROMOTE BETTER FARMING

PROTECT GRASSED WATERWAYS WITH PLOWS AND DISCS THAT LIFT ACROSS

It is one thing to seed and establish grassed waterways . . . quite another to have the field tools that will protect these waterways. Massey-Harris has them.

Shown above, for example, is a Massey-Harris heavy duty Goble mounted disc that can be raised and carried across the waterway . . . avoids tearing up the turf. Similarly, mounted plows for the Massey-Harris Tractor can be lifted and carried across grassed waterways — without even so much as slowing down the tractor. For pull-type discs, plows, heavy-duty field cultivators a Massey-Harris remote hydraulic control can be installed to straighten and angle the discs while "on the go" — as well as lift the equipment.

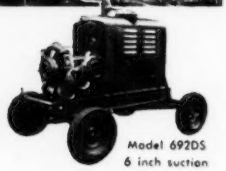
These are just a few examples of how Massey-Harris tools help you promote soil conservation. It shows that we must all work together to HELP SAVE OUR SOIL. The Massey-Harris Company, Quality Avenue, Racine, Wisconsin.

Make it a Massey-Harris

EVERY AGRICULTURAL ENGINEER HAS A STAKE IN SOIL CONSERVATION

Marlow WATER WIZARD
SPRINKLER IRRIGATION PUMPS

. . . dependable
. . . economical
. . . easy to use

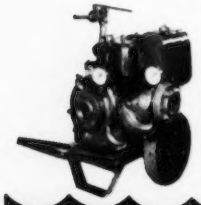


Model 692DS
6 inch suction
and discharge

Modern design — These pumps embody the latest features for modern sprinkler irrigation. Marlow Water Wizards are new . . . designed especially for today's new pressure and capacity requirements. They will supply water dependably. They are thrifty and virtually maintenance-free in operation and are built to last for years.

Complete size range — Marlow centrifugal irrigation pumps offer a wide choice of models for *any* job. Available in 14 models, sizes 2- to 6-inch, including two models designed especially for 2- and 3-acre sprinklers. Capacities 50 to 1900 GPM; pressures 30 to 200 PSI. Gasoline and Diesel engine driven; all models may be equipped for belt drive or supplied direct coupled to electric motors. Skid mounted or with steel wheels or rubber tires.

Model 3125 3 inch
suction and discharge



If the question is Sprinkler irrigation pumps, Marlow is the answer.

Write for full information.

MARLOW PUMPS 255 GREENWOOD AVENUE RIDGEWOOD, NEW JERSEY

Manufacturers of Quality Pumps for Over a Quarter of a Century

RESEARCH NOTES

ASAE members and friends are invited to supply, for publication under this heading, brief news notes and reports on research activities of special agricultural engineering interest, whether of federal or state agencies or of manufacturing and service organizations. This may include announcements of new projects, concise progress reports giving new and timely data, etc. Address: Editor, AGRICULTURAL ENGINEERING, St. Joseph, Mich.

USDA Notes on Castor Bean Strippers, Two-Temperature Refrigerators, Molding of Stored Grains, and Cotton Ginning

Strippers Harvest Castor Beans. Tractor-mounted, two-row, castor-bean strippers, developed through the cooperative efforts of agricultural engineers and agronomists of the U.S. Department of Agriculture and the Oklahoma Agricultural Experiment Station, were used last fall to harvest a large part of the 80,000 acres planted to this defense-important oil crop.

The critical industrial need for castor oil, to be used in protective coatings for equipment, as a plasticizer in fabrics, in lubricating oils and greases, and in hydraulic fluid, prompted the USDA's CCC to enter into contract with a machinery manufacturer to build sixty of these strippers for use in Oklahoma and Texas harvest fields.

Engineers and agronomists successfully developed and tested a one-row stripper last year, but the urgent need for a machine that could handle a bigger share of this year's harvest, resulted in the rapid development of a two-row machine which got much of its field testing as it harvested the 1951 crop. The sixty strippers were placed at strategic locations throughout the Southwest by CCC representatives to be used by custom operators in harvesting the castor bean crop.

The two-row stripper employs a beater mechanism that strips the castor bean capsules (pods) from the plants without pulling the plants from the ground. A gathering unit on the harvester moves the castor plants gently into reach of the fabric beaters, which shake and strip the capsules from the plant. Parallel augers move the capsules to an elevator which carries them to a training wagon.

Castor beans to be harvested by the stripper can be grown generally throughout the southern Oklahoma-Texas area, and it is anticipated that about 200,000 acres of the beans will be planted in 1952.

* * *

Two-Temperature Farm Refrigerator. Plans are now available for a two-temperature, walk-in refrigerator developed by the USDA. Working drawings (Plan No. 7102) for the two-temperature walk-in refrigerator for the farm may be obtained through the extension agricultural engineer at many of the state agricultural colleges.

Research to develop an efficient and convenient all-purpose farm refrigerator was begun following a survey of 160 home-built, walk-in, two-temperature installations in use on farms. Although the families considered their refrigerators assets, many found them inadequate. In general, systems in use were not designed to meet the farmers' needs. No established design was followed either in construction of the refrigerators or in the refrigeration systems. Many were found to be improperly constructed or poorly insulated, providing inefficient refrigeration. Others were too small, poorly arranged, or inconveniently located.

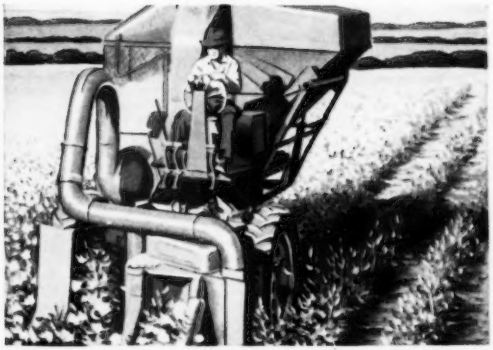
The new refrigerator-freezer has been designed by USDA refrigeration specialists after months of research with experimental units. The refrigerator freezer is planned so that it may be constructed by the farmer himself, either inside another building or as a separate structure. The Department recommends that technical help from a refrigerator service man be obtained to install the refrigeration equipment.

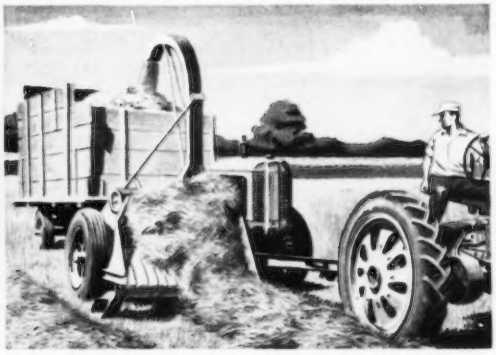
* * *

Surface Molding of Stored Grains Prevented. Surface molding of dry, stored grain can be prevented by drawing cooling air through it during the fall and winter, according to research findings of USDA agricultural engineers and midwest state agricultural experiment stations.

Storing grain or shelled corn at a safe moisture content is no guarantee against surface spoilage. Although the average moisture content of the stored grain may not change, cool weather often causes the moisture of the grain to move from the relatively warm grain in the center of the storage to the colder grain at the surface. As the surface grain becomes cooled by outside temperatures in the fall and winter, the temperature difference throughout the grain results in air currents, which move from the warmer central mass of grain to the surface, carrying moisture with them. As this moisture-laden air reaches the colder surface, some of the moisture condenses, increasing the surface grain's moisture content beyond the point of safe storage.

(Continued on page 108)





Each made to meet a special need

Just as harvesting equipment is designed to meet specific farming needs, so various Armco Steels are especially suited to different types of farm service.

When farm equipment has to fight rust, hold paint longer, or withstand a combination of heat and corrosion, there's an Armco Special-Purpose Steel for each particular job.

One of these steels is Armco ZINCGRIP-PAINTGRIP. It has a protective zinc "skin" that clings tightly to the base metal during forming or drawing — plus a mill-applied Bonderized finish that *takes* and *preserves* paint.

The result is *unbroken* rust protection and longer paint life. To the farmer, this means a saving in maintenance costs for combines, corn pickers, grain drills and other equipment.

Other Armco Special-Purpose Steels include an aluminum-coated steel that resists heat damage in crop dryers, brooders and tobacco-curing stoves . . . a whole family of solid, rustless Armco Stainless Steels for hand sprayers, hog waterers and dairy equipment.

Many farmers look for the Armco trademark on the farm implements and equipment they buy. From experience, they know it stands for steels that give longer service at lower cost *because they're made for the job.*

ARMCO STEEL CORPORATION

MIDDLETOWN, OHIO, WITH PLANTS AND SALES OFFICES FROM COAST TO COAST
THE ARMCO INTERNATIONAL CORPORATION, WORLD-WIDE

ARMCO

MORE SCRAP FOR MORE STEEL More steel scrap is needed for top steel production. The new furnaces the steel industry is building cannot be operated at capacity with the present scrap supply. To help the nation — and yourself — sell your steel scrap now!

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orifice
tips . . .
a feature of
SPRAYING SYSTEMS
TeeJet
SPRAY NOZZLES
Merely by changing orifice tips, users of TeeJet Spray Nozzles may change over from one type of spraying to another. Change only the tip and you've changed the nozzle! Choice of hundreds of tip sizes for any type of spraying. Only TeeJet Spray Nozzles provide all of these advantages:
• Choice of flat spray and cone spray tips for solutable chemicals . . . disc type cone spray and Cone-Jet tips for chemicals with suspended solids . . . all interchangeable.
• Factory testing of every nozzle before shipment.
• Comprehensive reference catalogs, to give you easy selection of the exact spray nozzle needed for any application.
• Precision orifice design . . . the design that guarantees positive, predictable orifice diameters as specified, for exact spray nozzle performance.
• Built-in strainers . . . monel metal screens or milled brass cores to fit each need.
• Easy tip adjustment on all flat spray tips. Milled flat tip surfaces are parallel to plane of the flat spray.
TeeJet Spray Nozzles are made for use with all types of spraying equipment. Write for Bulletin 58.
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A PIONEER IN
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IRRIGATION
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There's a Rain Bird Sprinkler to fit every irrigation problem —19 in all, ranging in size from 1½ G.P.M. at 3 pounds pressure to 610 G.P.M. at 120 pounds pressure.
NO. 40
If yours is a special irrigation problem, consult our research department now.
National RAIN BIRD Sales & Engineering Corp.
AZUSA, CALIFORNIA

RESEARCH NOTES

(Continued from page 106)

Experiments in the midwest have proved that low-velocity, cool air forced through the grain controls moisture migration. Cooling should start early in the fall when temperatures get down near 40 deg, or when outside air is at least 10 deg cooler than that of the grain at the storage center. Early fall cooling is especially important if the moisture content of the grain is slightly above the safe storage level. Cooling can be stopped in the winter as soon as all of the grain is cooled at a near freezing temperature.

• • •

Cotton Ginning Research. Development of equipment for cleaning cotton ahead of ginning, and of the lint flue cleaner at gins, are recent USDA research achievements that are helping to meet the problem of handling trashier cottons in the South. Such cottons have been prevalent with advent of the mechanical harvesters and strippers that now are being used by thousands of growers.

Charles M. Merkel, engineer in charge of investigations at the U.S. Cotton Ginning Laboratory, Stoneville, Miss., reports that by using more efficient cleaners, ginners can now produce higher average grades of fiber from machine-picked cotton than they can obtain from delayed or poor hand-harvested cotton. Currently engineers and cotton technologists of the Department and in private industry are seeking answers to such problems as grass and stick removal, trash disposal, and controlled drying during ginning.

The extra drying equipment installed in gins to handle the higher moisture content machine-picked cotton has made it possible in some instances for ginners to overdry cotton, resulting in reduced fiber quality. The problem confronting the ginner is that of making quick adjustments in his drying equipment when handling hand-picked cotton containing little excess moisture as well as machine-picked cotton with a high moisture content. Automatic controls are being sought so that the best moisture content can be obtained for each operation and each bale of cotton. Development of such a controlled conditioning process is being investigated at the USDA laboratory.

North Carolina Notes on Curing Bright Leaf Tobacco

THE curing operation has a direct effect on saleable leaf value and influences methods and procedures for all the other phases of bright-leaf tobacco production. For this reason the North Carolina Agricultural Experiment Station, in cooperation with the U. S. Department of Agriculture and the N. C. Department of Agriculture, is directing considerable effort to the study of the curing process. In addition to investigations of the conventional curing methods, studies of fundamentals are being initiated to formulate basic principles on which to develop, if possible, a more practical curing method.

Results to date indicate that bright-leaf tobacco will yellow at an applicable rate when suitably piled together to allow a temperature rise resulting from the associated heats of chemical reactions. The desirable yellow color developed in this manner can be fixed if the leaves are dried out at a comparatively rapid rate. However, F. J. Hassler, experiment station agricultural engineer, reports that the rate of color change from desirable yellow to undesirable reddish brown increases with leaf temperature and at 134 F (approximately) this undesirable color change is somewhat spontaneous, which limits the drying rate. He found that shredding the yellowed leaf effected a 5 to 8 F decrease in the leaf temperature as compared to the normal leaf and the more free release of water by the plant allowed rapid drying of the shredded leaf with the resultant fixation of the desirable yellow color. Other quality characteristics of the cured leaf are being determined.

Further study revealed that color change can be arrested by subjecting the leaf to a "temperature shock," taking advantage of the physiological factor referred to as thermal killing of the plant tissue. Bringing a hot plate at 550 F (approximately) in sharp contact with the leaf, which raised its temperature from 80 to 220 F in 3 sec, proves adequate for arresting color change and induces in the leaf the desirable property of more free release of its water. Exposing the leaf to infrared radiation of an intensity of 13 w per sq in (approximately), which raised its temperature from 80 to 230 F in 30 sec, produces similar results. Such temperature shocking causes more rapid drying in the normal atmosphere or permits so-called "flash drying" by the addition of supplemental heat. These findings, conceivably, have a potential application in future attempts for mechanization provided the other quality characteristics of the leaf are maintained.

The water relations of the tobacco leaf are being studied by correlating leaf temperature with drying rates and equilibrium vapor pressure at different states of cure. Research is being planned for the study of the specific heat and heats of chemical reaction of the leaf, and the latent heat of evaporation of water from the tobacco leaf. The object of these studies is to determine values required for the formulation of thermodynamic relationships on which to establish the water-energy relations of the tobacco leaf as it cures.

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AGRICULTURAL APPLICATIONS INCLUDE: Tail wheel mounting bracket, hay baler knotter drive (lower gears), hay baler ring gears, gear carriers, worm and wheel, rear axle housing, plow spring release hitch.

ADDITIONAL AGRICULTURAL APPLICATIONS EITHER ON AN EXPERIMENTAL OR PRODUCTION BASIS AT PRESENT TIME: Tractor clutch plates, tractor transmission housing, front axle supports, implement sprockets, chilled plow shares, mower guards, tractor pulleys.

AVAILABILITY—Send us details of your prospective uses, so that we may suggest a source of supply from some 100 authorized foundries now producing ductile iron under patent licenses. Request a list of available publications on ductile iron... mail the coupon now.

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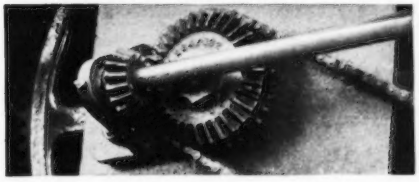
This tractor spring release hitch, with high yield strength, is only one of many farm equipment components improved when cast in ductile iron.



The ductile iron bevel gears used on hay balers shown here were produced to provide high wear resistance and toughness.

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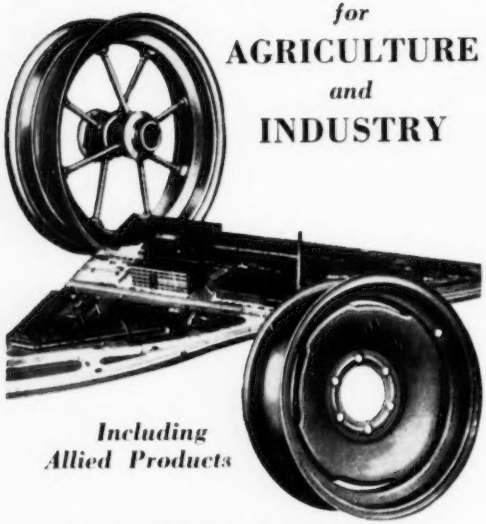

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Controls for Poultry Laying Battery

(*Continued from page 90*)

relay rather than the feed-elevator motor, the bucket-tripping mechanism and the conveyor belt clutch as above. The transfer switch has already provided for this by stepping its contact arm ahead to the next contact point. This second contact point is connected to the operating coil of the locking-release relay 93 so that at 5:10, when another signal-circuit impulse is sent out by the program timer, the relay contacts will be opened and the delivery operation for the first feeding level stopped. The next impulse from the program timer must set in motion the feed-delivery process for the second feeding level. Consequently, the transfer switch automatically shifts its contact arm ahead to the third contact point so that the 5:15 impulse from the timer can effect the second-lever feed delivery. In this manner, the transfer switch acts to operate the different mechanisms in a definite time sequence throughout the day.

MECHANISM APPLICATIONS

Although the mechanical and electrical devices described in this report were developed as integral parts of a laying battery, it is hoped that they may find applications in other plans of poultry and animal care. It is believed that the "Autopos" clutch can be effectively used in many feeding and materials-handling applications where slow-moving conveyor belts are used at single or multiple levels. The feeding and watering systems are applicable to other battery units or to buildings where livestock is cared for on more than one level. The egg-collection and droppings-removal mechanisms are easily divorced from a battery scheme and can be used to save steps and labor in other locations. The Zenith program timer and the Autdelay transfer switch, when used together, can control almost an indefinite number of electrical devices either concurrently or in a sequence that may easily be rearranged or shifted as the occasion demands.

ECONOMIC CONSIDERATIONS

The question has been asked by many sincere and interested individuals if the mechanisms described in this report are economically practical or if their cost would prohibit their use. Of course, it is very difficult to determine, at the research stage, if a new development will be commercially acceptable or if it can be efficiently mass produced in sufficient quantities to lower the price to a reasonable level. However, when it is possible to accomplish by electrical means tasks that have normally been done manually, there is a tremendous economic leverage exerted in favor of electric power. With electrical energy at 5c per kw-hr and human labor at $1 per hr, it costs approximately 270 times as much to do the same amount of physical work manually as it does electrically. Electrical equipment costs can thus be rapidly liquidated.

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1. An Automatic Clutch for the Remote Control of Multiple, Slow-Speed Conveyor Belts, by Stanley J. Otis, Norman J. Wedekind and Robert N. Schumann, United Industries, Madison, Wis., 1949.

2. Automatic Feeding and Watering for a Laying Battery, by Stanley J. Otis and Robert N. Schumann, United Industries, Madison, Wis., 1950.

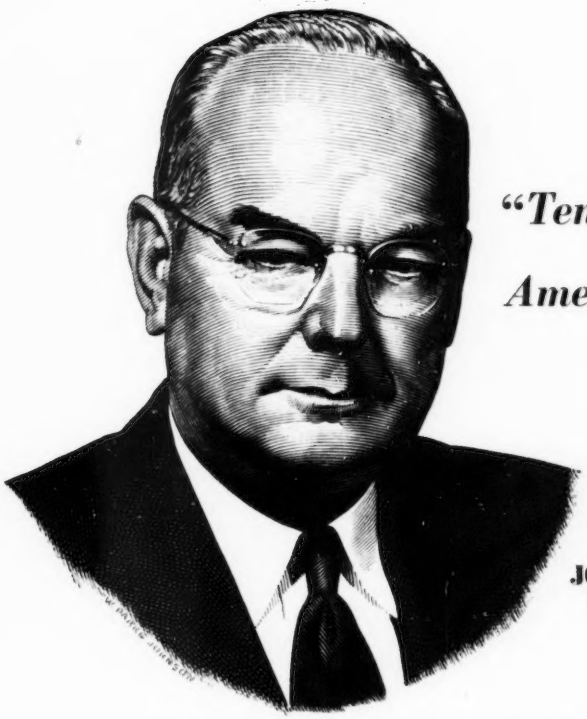
3. Automatic Egg Collection and Weighing for a Laying Battery, by Stanley J. Otis and Robert N. Schumann, United Industries, Madison, Wis., 1950.

4. Automatic Actuation and Transfer of Sequence Control Circuits, by Stanley J. Otis and Robert N. Schumann, United Industries, Madison, Wis., 1950.

NEW BULLETINS

Wear Tests on Pumps for Agricultural Field Sprayers, by James E. Garton and M. J. Morgan. Oklahoma Agricultural Experiment Station (Stillwater) Bulletin No. B-375 (October, 1951). Brief report on wear tests of gear and roller pumps, pumping a mixture of water with kaolin, a common diluent in wettable powder insecticides and herbicides.

Design Studies for a Closed-Jet Water Tunnel, by John E. Ripken. Technical Paper No. 9, Series B (August, 1951) St. Anthony Falls Hydraulic Laboratory (Minneapolis, Minn.) $2.00. This is a 146-page report bringing together results and reports on studies over a period of years dealing with test sections, contraction, diffusers, vaned elbows, and pumps.



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Personnel Service Bulletin

The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings, is not intended to imply any specific level of proficiency, or registration, or license as a professional engineer.

NOTE: In this bulletin the following listings still current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated:

POSITIONS OPEN: 1951—AUGUST—O-320-543. SEPTEMBER—O-340-539, 355-542. OCTOBER—O-401-544. DECEMBER—O-457-547, 451-548, 450-549, 475-550, 480-551. 1952 JANUARY—O-494-552, 484-553, 492-554, 498-555.

POSITIONS WANTED: MAY—W-253-54, 276-56. JUNE—W-242-60. AUGUST — W-292-71. SEPTEMBER — W-331-72, 355-75, 334-74. OCTOBER—W-388-76, 391-78. NOVEMBER—W-419-80. DECEMBER—W-459-81, 464-82, 461-85, 454-84, 467-85, 471-87, 470-88, 477-89. 1952 JANUARY—W-485-90, 488-91.

NEW POSITIONS OPEN

ASSISTANT ENGINEER to plan, design, and estimate on an expanding line of prefabricated farm buildings, and to develop check lists and assembly instruction sheets, with manufacturer in Nebraska. BS deg in agricultural engineering or equivalent. Farm, construction, or architectural experience desirable. Must be good draftsman. Good co-operator with aptitude for commercial development engineering. Good opportunity in growing organization. Age 25-30. Salary open. O-503-556

COPYWRITERS (four openings) for writing, development, and direction of product information on agricultural equipment with agency for a major full-line manufacturer. Location, Chicago. BS deg in agricultural engineering or agricultural journalism. Farm, publication, writing, or retail merchandising experience. Able to write and to contact client for information. Age 24-35. Salary $5,000-$10,000. O-502-557

NEW POSITIONS WANTED

DESIGN, development, or research in power and machinery field, with manufacturer anywhere in northern U.S.A. BS deg in agricultural engineering expected in June, University of Vermont. New England dairy farm background. Two college summer vacations as farmhand, one as draftsman. Part time work in college as maintenance man and assistant mechanic. Married. Age 22. No disability. Available June 20. Salary open. W-528-95

DESIGN, development, or research in power and machinery field with manufacturer, processor or farming operation, anywhere in U.S.A. BS deg in agricultural engineering expected in June, University of Vermont. Farm laborer 3 to 6 mo per year, 1945 and 1948. Crew leader, U.S. Forest Service, 3 mo, 1946. One year as full time test man on electronic equipment, General Electric Co., Burlington, Vt., concurrent with college work. War enlisted service in Army 1½ yr, chief clerk in rail transportation. Married. Age 23. No disability. Available June 30. Salary open. W-529-96

DESIGN, development, research, or writing in public service or private industry, preferably outside of U.S.A. BS deg in agricultural engineering expected in June, University of Idaho. Summer experience on farms as combine operator, cat skinner, and foreman of hay and harvest crew. One summer on layout and maintenance of university experimental plots. Single. Age 23. No disability. Available June 16. Salary $3700. W-504-92

DESIGN, development, research, extension, or teaching in power and machinery, rural electric, or soil and water field in industry or public service, preferably in East or Midwest, possibly outside of U.S. BS deg in agricultural engineering, February, 1950, University of Maine. Part time graduate work in education, Hillyer College. Background on mechanized family farm. Assistant county agent 5 mo. Assistant county club agent September 1950 to date (current position). Age 28. No disability. Available in June or possibly sooner. Salary $3800. W-487-93

EXTENSION, teaching, research, service, or writing in power and machinery field, with industry or public service, anywhere in U.S.A. or Canada. BS deg in agriculture, major in agricultural engineering, 1950, University of British Columbia. MS deg, 1951, University of Saskatchewan. Student instructor 3 yr. Shop superintendent for diesel logging operation 6 mo. Product education and service manager (present position) with distributor of agricultural and industrial machines in Saskatchewan. Married. Age 25. No disability. Available on reasonable notice. Salary $3800-4200. W-516-94

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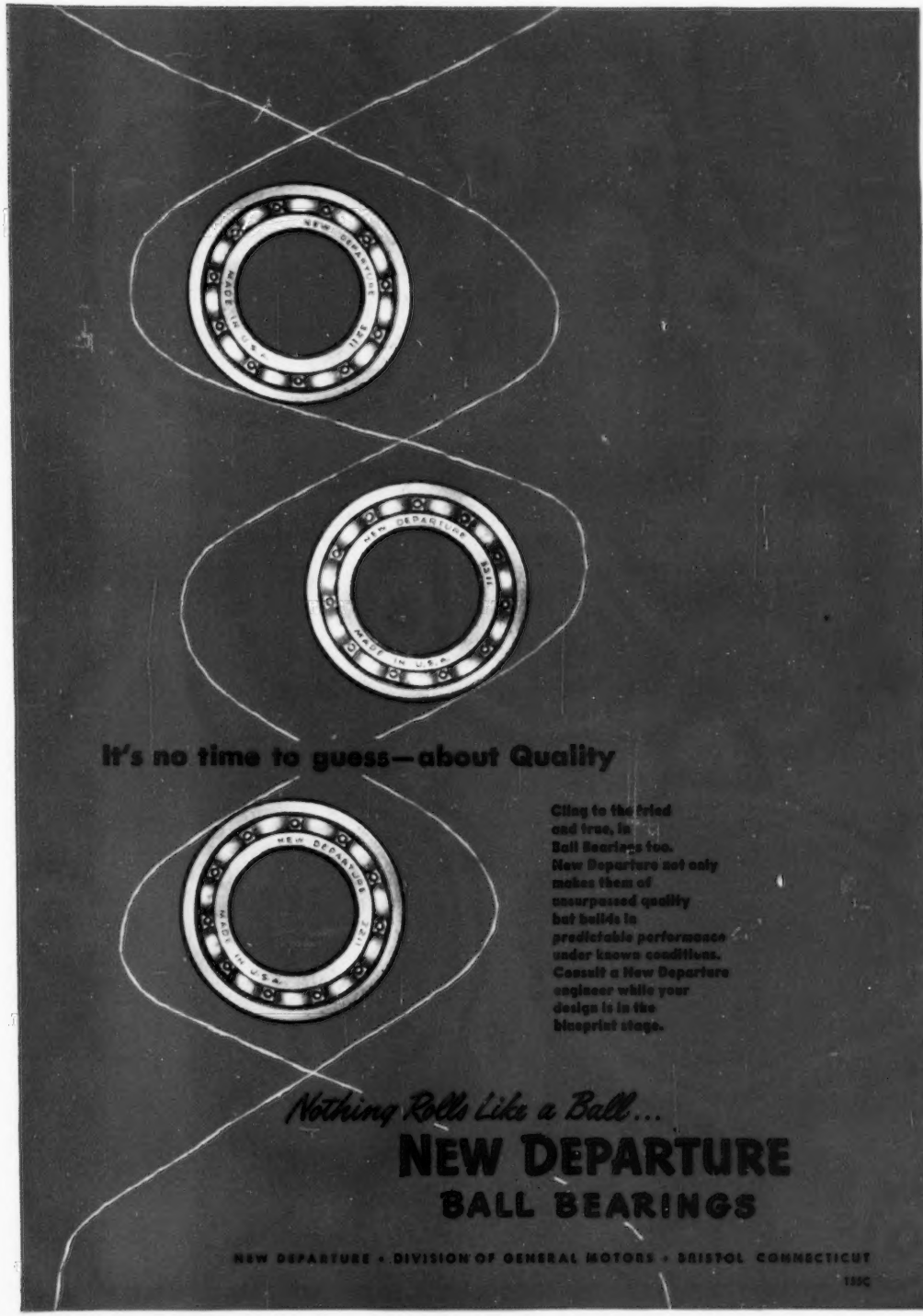
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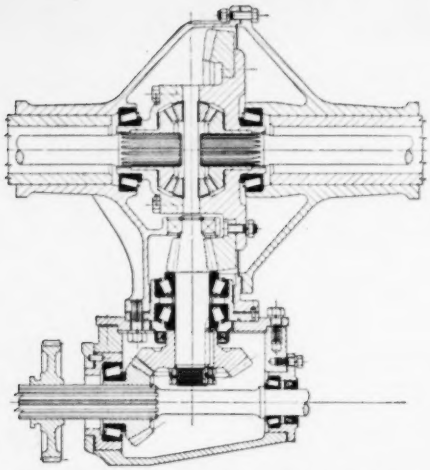
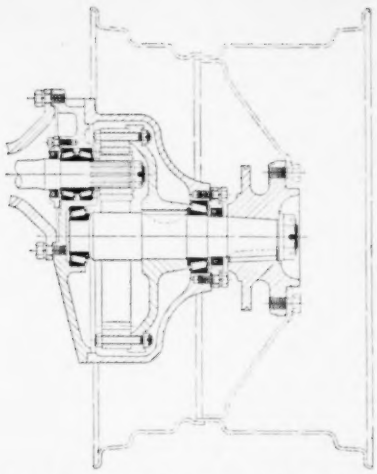


In this John Deere No. 55 Self-Propelled Combine drive, imput shaft and differential bearings are directly mounted and adjusted with thin metal shims. Pinion shaft bearings are mounted indirectly and adjusted by cone spacers.



In the No. 55, Timken bearings on the bull pinion are directly mounted and adjusted by shims. Toe axle shaft uses two single row Timken bearings directly mounted and shim-adjusted.

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